Scientific Programming for Fuzzy System Modeling of Complex Industry Data

Lead Guest Editor: Maozhen Li
Guest Editors: Tongguang Ni and Zhifan Gao

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Retraction

Retracted: A Quantitative Enhancement Mechanism of University Students' Employability and Entrepreneurship Based on Deep Learning in the Context of the Digital Era

Scientific Programming

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] X. Meng, G. Ren, and W. Huang, "A Quantitative Enhancement Mechanism of University Students' Employability and Entrepreneurship Based on Deep Learning in the Context of the Digital Era," *Scientific Programming*, vol. 2021, Article ID 7245465, 12 pages, 2021.

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Research Article

Architecture of Deep Convolutional Encoder-Decoder Networks for Building Footprint Semantic Segmentation

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Building extraction from high-resolution aerial images is critical in geospatial applications such as telecommunications, dynamic urban monitoring, updating geographic databases, urban planning, disaster monitoring, and navigation. Automatic building extraction is a massive task because buildings in various places have varied spectral and geometric qualities. As a result, traditional image processing approaches are insufficient for autonomous building extraction from high-resolution aerial imaging applications. Automatic object extraction from high-resolution images has been achieved using semantic segmentation and deep learning models, which have become increasingly important in recent years. In this study, the U-Net model was used for building extraction, initially designed for biomedical image analysis. The encoder part of the U-Net model has been improved with ResNet50, VGG19, VGG16, DenseNet169, and Xception. However, three other models have been implemented to test the performance of the model studied: PSPNet, FPN, and LinkNet. The performance analysis through the intersection of union method has shown that U-Net with the VGG16 encoder presents the best results compared to the other models with a high IoU score of 83.06%. This research aims to examine the effectiveness of these four approaches for extracting buildings from high-resolution aerial data.

1. Introduction

Collecting urban geographic information and updating data timely are crucial and vital challenges for better management of cities in the fast urbanization and building of megacities. The accuracy of information extraction may be considerably improved by using high-resolution remote sensing images. Experts and scholars from all over the world have focused on remote sensing data classification methods in recent decades, ranging from supervised and unsupervised classifications based on traditional statistical analysis [1]. Among these, the pixel-based statistical classification approach has emerged as the most popular and well developed, with promising results in particular domains [2]. On the other hand, traditional pixel-based classification algorithms primarily use spectral data and have limited effectiveness in categorizing high-resolution multispectral urban images with similar spectra into separate categories [3]. To develop more accurate categorization maps, geographic information such as geometric and spatial characteristics and textural information must be used.

In recent years, object-oriented classification algorithms have attracted researchers' interest [3, 4]. It has been demonstrated to have the ability to overcome the suffering from some forms with per-pixel analysis, such as the omission of geometric and contextual information. The fundamental concept is to divide the image into objects with specific meanings and then categorize them using the items spectral, form, and textural properties. This technique considers additional discriminative features and conforms to human visual interpretation patterns, resulting in a new way of thinking about data extraction [5]. While several studies have demonstrated the benefits of object-based classification over pixel-based classification, there has been less focus on its possible drawbacks. However, the object-based technique has its own set of constraints. Image segmentation errors include both over-segmentation and under-segmentation. These segmentation issues can affect the categorizing process in two ways: (1) Poorly segmented image objects with over-segmentation or under-segmentation errors produce image objects that span multiple classes, introducing classification errors because all pixels in each mixed image object must be assigned to the same class; (2) features extracted from poorly segmented image objects with over-segmentation or under-segmentation errors do not represent the properties of real objects on the Earth's surface (e.g., shape and surface area), so they may not be useful and may even reduce the accuracy of the classification.

Image segmentation is an essential and vital phase in (GEographic) Object-Based Image Analysis (GEOBIA or OBIA). The quality of image segmentation significantly influences the final feature extraction and classification in OBIA. In traditional segmentation methods, images are usually divided into several disjoint regions based on grayscale, color, texture, and shape. Typical segmentation methods include pixel-based statistical classification, segmentation methods based on thresholds, edges, regions, and graph theory, and object-based image segmentation.

The basic idea of the threshold-based segmentation method is to calculate the grayscale threshold based on the grayscale features of the image and compare the grayscale value of each pixel of the image with the threshold to obtain its category. For example, Li et al. [6] used the wavelet transform and adaptive global threshold method to extract the labelling information of building groups according to the distribution and texture characteristics of building groups to achieve segmentation; Wu et al. [7] proposed a method based on the line intercept histogram. Multi-threshold segmentation methods and edge-based segmentation methods [8] mainly perform edge detection based on the sudden change of image edge grayscale, color, texture, and other features. Differential operators such as Prewitt [9] perform edge detection on the image, identify the edge information of the image, and complete the segmentation. The basic idea of the segmentation method based on graph theory is to associate the image segmentation problem with the minimum segmentation problem of the graph and finally realize the segmentation effect. For example, Felzenszwalb et al. [10] introduced an image segmentation method based on graph representation, proposed a variable component model algorithm based on the greedy clustering algorithm, and established a segmentation algorithm based on graph theory. However, due to the rich spectral information contained in remote sensing images, traditional feature extraction methods still have significant limitations for demanding remote sensing image segmentation application scenarios, and their classification accuracy cannot meet the actual needs for dealing with huge image data and serious image interference. Therefore, traditional classifiers are unsuitable for complex image classification and, more precisely, building extraction.

Urban system studies are promising for using particular resolution and very high spatial satellite image data. Thus, for Earth monitoring, the development of various sensors has substantially expanded the availability of high-resolution remote sensing images since the launch of the first satellite, giving accurate terrestrial scene interpretation and an enormous potential for meaningful. Identifying rooftops is one of the most challenging satellite image analyses, but essential tasks for object extraction. Many remote sensing applications, such as disaster monitoring, geographic databases, urban planning, etc., can benefit from this data. However, with high spatial and spectral quality RS data, manually distinguishing buildings from other objects and delineating their outlines are time consuming and costly. As a result, there have been several attempts to develop automated building extraction technologies.

Some algorithms for building detection based on high-resolution satellite and aerial data use specific building appearance criteria, such as uniform spectral reflectance values. The fundamental issue with these techniques is that the building is confused with other objects having similar spectral reflectance. Many methods for building extraction use multispectral images that provide for a scene set criteria height information, like relatively homogenous structures following a given pattern. However, these techniques are severely constrained since the established criteria only work for specific types of buildings and do not apply to regions with complex and varied structures. Different data sources might provide each other with complementing information.

In recent years, deep learning has shown significant promise for meeting the challenging demands of remote sensing image processing. Deep learning has shown to be a very effective collection of technologies in recent years, sometimes even surpassing human abilities to perform highly computational jobs. The RS community's interest in deep learning approaches is expanding rapidly, and several architectures have been developed in recent years to handle RS difficulties, frequently with excellent results. Deep learning is an emerging machine learning algorithm that has attracted extensive attention from researchers because of its remarkable effect on image feature learning. Compared with traditional image classification methods, it does not require artificial feature description and extraction of target images but learns features from training samples autonomously through neural networks and extracts higher-dimensional and abstract features, and these features related to the classifier are closely related and solves the difficult problem of manual feature extraction and classifier selection. It is an end-to-end model. The essential advantage of the deep learning-based image classification method compared to the traditional image classification method is that it can automatically learn more abstract data features through the deep architecture without designing specific artificial features for specific image data or classification methods, significantly improving the performance of image classification. Deep Learning (DL) outperforms its predecessors significantly; it is based on a traditional neural network. Furthermore, in order to construct multi-layer learning models, DL uses both transformations and graph technologies at the same time.

The latest DL algorithms have achieved excellent results in various applications, including natural language processing (NLP), visual data processing, and audio and voice processing. Convolutional neural networks (CNNs) with more hidden layers have a more complicated network structure and can learn and express features more effectively than classic machine learning approaches [11, 12]. In remote sensing, the use of CNN has become crucial with the appearance of multispectral data at a very high spatial resolution. However, Figure 1 shows the number of publications in the last six years that use CNN and different techniques to classify high-resolution satellite data. This exponential number of publications shows the importance of the deep learning approach in automatic object recognition from high and very high spatial and spectral resolution images.

High-resolution remote sensing images have rich spatial information but contain fewer bands. In order to extract abstract features with sufficient discriminative power and robustness, in recent years, people mainly automatically extract deep-level features from image data through learning methods. CNN is commonly used in remote sensing image classification and can be divided into patch-based CNN and fully convolutional neural network (FCN) [13]. Patch-based CNN can effectively learn the spatial-spectral joint features of the pixels to be classified and their neighborhoods and has been widely used in the field of hyperspectral classification [14]. However, the network has a large number of repeated computations, which limits its application in large-scale high-resolution remote sensing imagery tasks. The trained FCNN can classify all the input image pixels through one forward pass, which is more efficient than the patch-based CNN [15]. Therefore, FCNN is widely used in large-scale high-resolution remote sensing image building extraction tasks [16]. The learning of image features by CNN is realized by optimizing each layer of convolution kernels in the network. The static structure of the network determines the mode of feature learning, and the data determines the specific feature extraction results, thus showing certain robustness. The feature fusion methods used in Residual Networks (ResNet) and DenseNets (DenseNet), that is, feature map addition and feature map connection, have a profound impact on CNN optimization research.

Building extraction from remote sensing images and comparing the performance of different models of the semantic segmentation network is our primary motivation for this paper. However, this paper allowed us to:

(i) show the importance of the deep learning model in the classification of satellite images with very high spatial resolution;

(ii) minimize subjectivity in urbanized areas with the most important step in the classification process being segmentation;

(iii) compare the four improved DL architecture (U-Net, LinkNet, FPN, and PSPNet) with five different initialized and pre-trained encoders (VGG16, VGG19, ResNet50, DenseNet169, and Xception);

(iv) improve overall classification accuracy in the Massachusetts aerial image dataset.

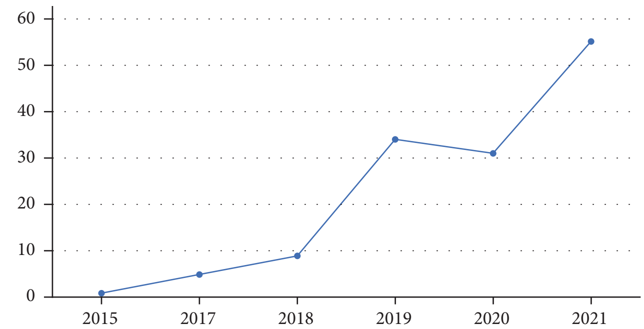

Figure 1: Number of published papers using CNN in the last six years according to the Scopus database.

2. Related Works

2.1. Semantic Segmentation. The semantic segmentation of remote sensing images aims to assign a land cover label to each pixel in the image, which can be understood as a pixel-level classification problem. Fully convolutional neural networks (FCN) were suggested by the authors in [17] to overcome the limitations of convolutional neural networks applied to the field of semantic segmentation. FCN has usually adopted an encoder-decoder system, with the encoder being a subsampling network, which is mainly used to learn multilevel semantic features. The decoder is generally defined as an oversampling network and is used primarily to map the semantic features learned by the encoder to the pixel space of the original resolution for pixel-level classification. Currently, in the field of remote sensing, researchers have made many improvements to FCN based on the characteristics of remote sensing images. For example, considering the rich and diverse categories of remote sensing objects and complex boundaries, Long et al. [18] improved the decoder by designing deconvolution and jump connections, improving the extraction effect of the edge details of the remote sensing object. To solve the problem of fuzzy edge details of objects extracted, the FCN method was proposed [19] by reducing the expansion factor of hole convolution to aggregate local features. Aiming at the multiscale problem of ground objects in complex remote sensing scenes, Hamaguchi et al. [20] proposed using a closed convolution neural network to complete information diffusion between feature maps at different levels to achieve multiscale feature fusion. As discussed elsewhere [21], based on the idea of clustered convolution design, an efficient spatial pyramid network with holes is proposed to complete the multiscale information extraction of remote sensing features. Moreover, considering the problem that FCN cannot adaptively take the long-range dependencies between different objects because of the fixed receptive field, the researchers used recurrent neural networks, self-attention mechanisms, and other methods to model the long-range contexts of remote sensing objects further to improve the semantics of segmentation accuracy [22].

2.2. Building Extraction. Several authors have utilized deep learning models to extract urban features from image data with very high spatial resolution, and with the progress of convolution, the degree of feature abstraction continues to increase, and the receptive field also increases, which inevitably leads to the loss of spatial details. Most of the FCNs used for building extraction use an encoder-decoder structure, which has the characteristics of level-by-level decoding and can recover spatial information. U-Net effectively recovers spatial information by fusing the feature maps of the encoded segment and the corresponding decoded segment and shows excellent potential in the task of building extraction [23]. In addition, buildings in high-resolution images have multi-scale characteristics, and the characteristics of vertical imaging in remote sensing images make their semantic features quite complex. There are many ground objects with similar colors and textures to building roofs.

The U-Net family [24] suggested two innovative classifiers for multi-object segmentation to extract roads and buildings. The multi-level context gating U-Net (MCG-U-Net) and the bi-directional ConvLSTM U-Net model are the two models discussed. The proposed methods generate detailed segmentation maps that preserve boundary information even in complex backgrounds by combining tightly-coupled convolutions, bidirectional ConvLSTM, and squeeze-and-excitation modules. The researchers also devised an essential efficient loss function known as boundary-aware loss (BAL), which allowed a network to focus on complex semantic segmentation regions such as overlapping areas, tiny objects, complex objects, and object boundaries while still delivering high-quality segmentation results. To employ building features from high-resolution aerial images, researchers [25] developed a unique deep neural network called the Seg-U-Net approach, which is a blend of Segnet and U-Net algorithms. They utilized the Massachusetts building dataset for their analysis. Consequently, the accuracy of the contributions increased to 92.73 percent. The authors in [26] established a unique multi-task loss to solve the difficulty of retaining semantic segmentation borders in high-resolution satellite images. The loss is based on differing output representations of the segmentation mask, according to the researchers, and biases the network to focus more on pixels near borders. The authors demonstrate that the technique outperforms state-of-the-art methods by 9.8% on the Intersection over Union (IoU) measure without extra post-processing steps using the Inria aerial image labeling dataset. The U-Net model with ResNet50 as an encoder was used in [27] to increase and improve the accuracy to extract buildings from the Massachusetts dataset.

3. Methodology

3.1. Sematic Segmentation with Fully Convolutional Network. To improve pixel-level image segmentation by traditional CNNs, the authors in [18] proposed a fully convolutional neural network, which achieves high accuracy in image-level classification and regression tasks, usually by connecting multiple fully connected layers after multiple convolutional layers. The N-dimensional feature vector is used to predict the probability value of each N category, and then the category of the input image is obtained. The difference between the above task and the extraction of the building in remote sensing images is that each pixel in the input image is classified to obtain a pixel-level classification result. Although CNN can define sliding windows centered on individual pixels and model the window features to obtain semantic segmentation results at the pixel level, the time complexity increases significantly due to the large amount of duplicate information generated by the overlapping areas between adjacent windows. In addition, the choice of window size will also be a challenge: A too-small window will lose target contextual information and reduce accuracy; a too-large window will increase the computational and memory load.

To address these issues, FCN has outperformed CNN. FCN uses deconvolution to up-sample high-dimensional feature maps to obtain prediction results similar to the input image, rather than utilizing fully connected layers to create feature vectors to forecast probabilities after multilayer convolution and pooling, as shown in Figure 2. This network topology prevents the propagation process from losing spatial information from the input image, allowing each pixel in the image to be predicted. Furthermore, the FCN does not have to perform a window-by-window calculation on the picture, dramatically improving computational efficiency.

Although FCN enhancement can reach the same segmentation result as the input image size, the predicted image is frequently too smooth, resulting in more severe information loss. The fundamental reason for this is that the input image is clustered many times, allowing neurons at the tail end to receive more information, resulting in a broader perceptual field. However, the image loses information, as a result making the edge contours extracted less desirable. Consequently, FCN integrates the low-dimensional feature map into the feature pyramid with the output after deconvolution to overcome the problem mentioned above and increase the accuracy of extracting detailed information. Consequently, U-Net [23] extends this idea of merging low dimensional features with high-dimensional features.

3.2. Model Used

3.2.1. U-Net Architecture. Figure 3 depicts the U-Net structure, consisting of two feature encoding and decoding steps. The raw input is convolved and subsampled layer by layer in the feature encoding step to obtain high-level semantic features with lower spatial resolution. In the decoding step, the underlying features are increased by a factor of 2 layer by layer through the upward convolution operation, concatenated with the same layer features in the encoding step, and returned to

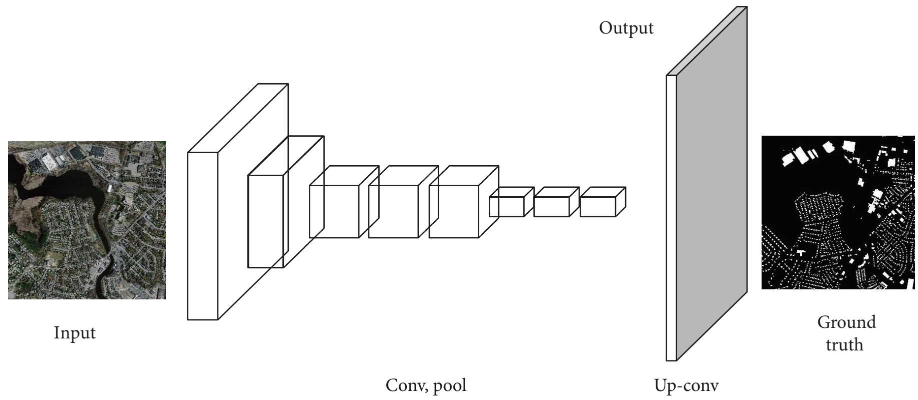

FIGURE 2: Architecture of fully convolutional neural networks.

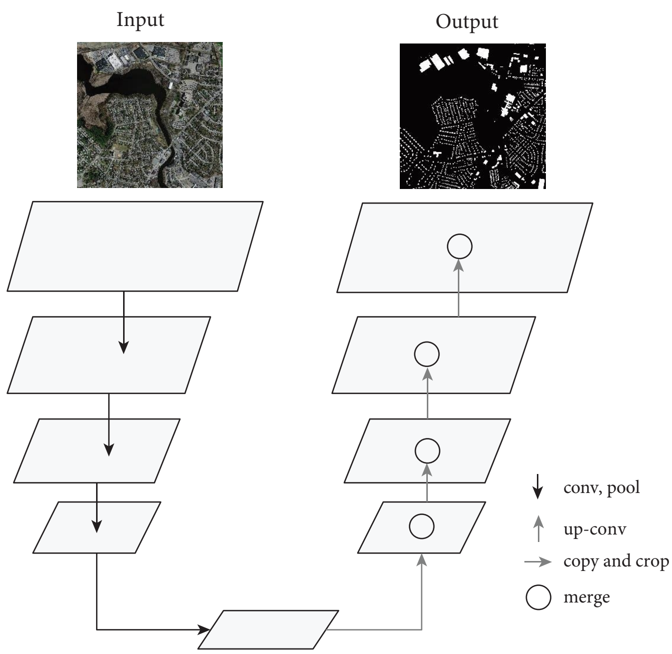

FIGURE 3: Architecture overview of U-Net.

the original image scale. At the original scale, the difference between the current model predictions and the ground truth reference is used to form the network parameters via back-propagation. U-Net only performs image pixel class classification in the last layer. Although U-Net uses some information from the previous layers in the encoding step, its ability to generalize to multi-scale information is limited.

3.2.2. Pyramid Scene Parsing Network (PSPNet). Multiscale information is also essential for enhancing the accuracy of semantic segmentation. The multiscale receptive field can learn information from objects of different sizes combined with the image scale context. For example, global scene classification can provide category distribution information for semantic image segmentation, and the pyramid clustering module obtains category distribution information by using clustering layers with larger convolution kernels. A spatial pyramid scene parsing network (PSPNet) [28] was proposed to acquire information about the overall scene. As shown in Figure 4, to extract the features from the input image, the convolutional neural network (CNN) model is used and the feature map is sent to the pyramid clustering model. In addition, to extract multiscale information from the images, the model integrates four parallel clustered features of different scales and transforms any size feature map into a fixed-length feature vector. To capture global features, 1x1 convolutions is used to reduce the number of channels to 1/4 of the original size after each clustering operation at different scales. Before ungrouping, the feature maps are restored to their original size using bilinear interpolation, and then connected to the feature maps before pooling. Finally, a convolutional layer generates the final prediction result. The spatial pyramid pooling model leverages distinct spatial information and combines global and local information to get a global understanding of the scene.

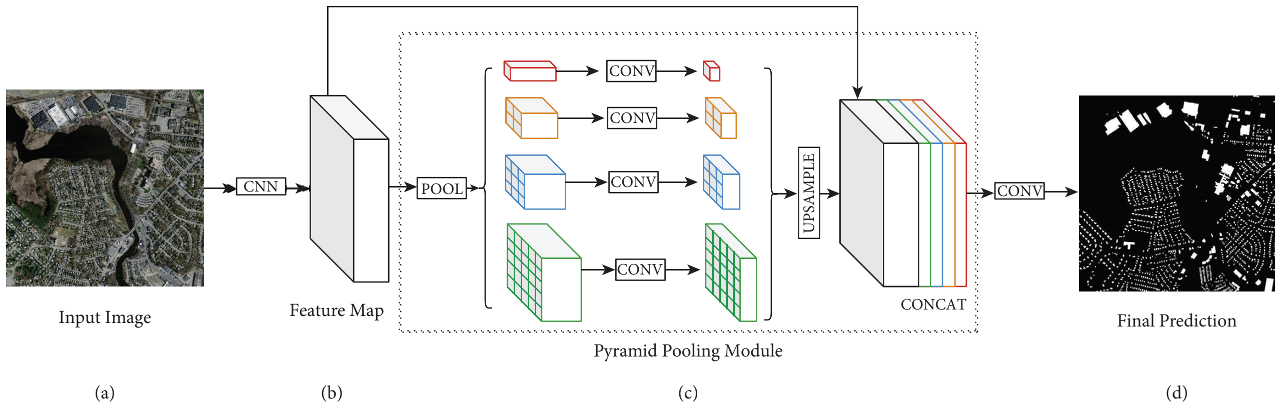

Figure 4: Architecture overview of PSPNet.

3.2.3. LinkNet. LinkNet, a real-time semantic segmentation network, was suggested by [29]. DeconvNet and SegNet employ clustering indices to recover spatial information lost during subsampling, whereas LinkNet sends spatial information directly from the encoder to the matching decoder, conserving as much of the image's spatial information as feasible. As shown in Figure 5, this method directly connects the shallow feature map in the encoder module to the decoder module of the corresponding size, that is, the output of each encoder module is used as the input of the corresponding decoder module, which not only uses the accurate position information of the shallow layer but also avoids adding redundant parameters and computations, resulting in improved computational speed while ensuring accuracy.

3.2.4. Feature Pyramid Network (FPN). Convolution and pooling operations are performed on the original image in convolutional neural networks to create feature maps of various layers and sizes. The network surface layer is more interested in detailed information, but the deep layer is more interested in semantic information, which might assist us in precisely detecting the target. As a result, the typical convolutional neural network makes predictions based on the feature maps of the final convolutional layer. The FPN is an end-to-end network in which feature maps are created through a succession of convolutional processes, predictions are formed at each step, and feature maps are utilized for each prediction layer identified at the appropriate resolution [30]. This guarantees that each layer has sufficient resolution and solid semantic characteristics. By weighing the outcomes of each prediction step, the FPN gets the final loss function. The principle is to accumulate surface and deep features, as the surface features provide more accurate location information. In contrast, the deep network's location information is inaccurate due to multiple subsampling and oversampling operations, and their combined use builds a deeper FPN (Figure 6) that integrates multiple layers of feature information and produces various features.

3.3. Backbone of Network. This study adopts models with end-to-end fully convolutional neural network structures, consisting of a decoder and an encoder. The encoder learns the target features hierarchically to gradually reduce the spatial resolution and gradually increase the receptive field. Among the features learned by the encoder, shallow features have more spatial information, including edge, contour, and location information, while deep features have more semantic category information. The decoder restores the spatial resolution of the features learned by the encoder and produces the prediction results with a similar spatial resolution as the input image. Considering in remote sensing that the scales of buildings images are quite different and there are both large buildings and small residential buildings in the same image, the spatial information lost in the encoding process should be compensated in the network design process, and the features of different scales should be integrated for decoding.

Verify the importance of the depth of the decoder and encoder layers and improve the proposed networks. This paper uses VGG16, VGG19, ResNet50, Densenet169, and Xception as pre-trained encoders on a large ImageNet dataset [31]. The addition of the encoder-decoder module aims mainly at improving the detailed information of the segmentation by restoring the original pixel information.

3.3.1. VGG as Backbone. VGG is a 16–19 layer deep convolutional network used by the Visual Geometry Group (VGG) at the University of Oxford in the 2014 ILSVRC (ImageNet) competition based on the AlexNet network. The model achieves a success rate of 92.5% in the top 5 of the validation set [32]. It inputs a color image of size $224*224$ px and classifies it into one of 1000 classes. Then, it returns a vector of size 1000, which contains the probabilities of belonging to each class. The automatic feature extraction exploits only the convolutional part of a pre-trained network. It uses it as a feature extractor of the images to feed the classifier. Using a multi-scale learning strategy to increase the amount of data, the model shows that the deeper the network, the better the results.

3.3.2. ResNet as Backbone. In [33], a ResNet to solve the problem of degraded deep network learning is proposed. ResNet adds constant mapping using a shortcut structure, which maps features X at the lower level directly to the

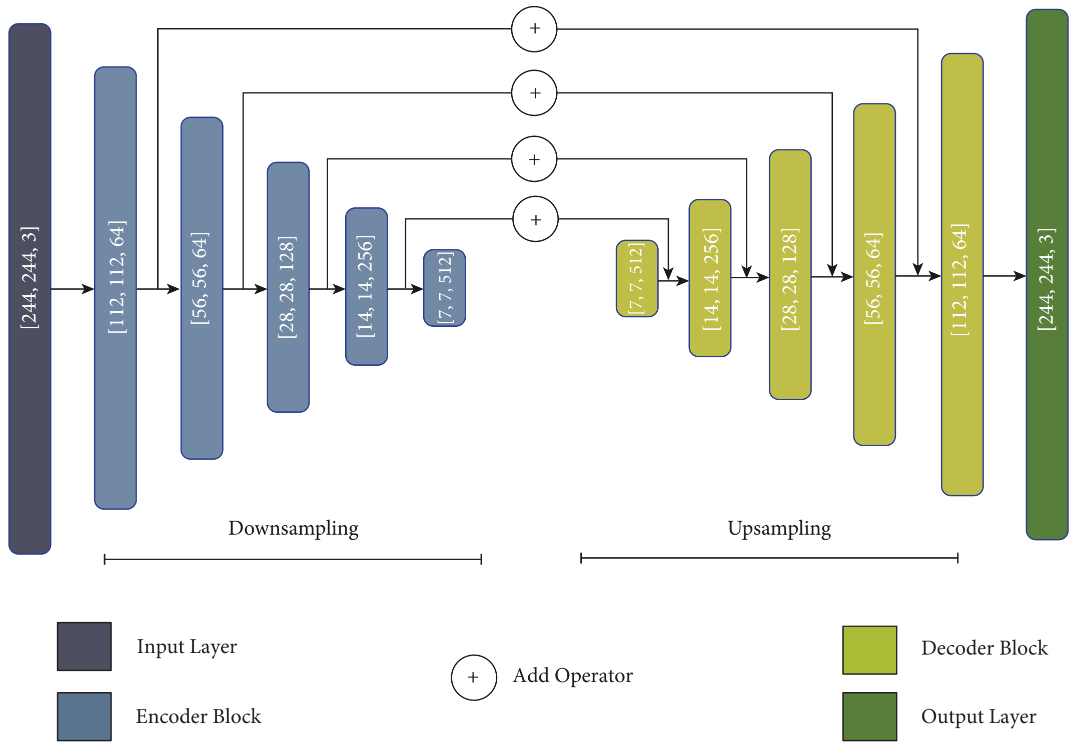

Figure 5: An illustration of the LinkNet architecture.

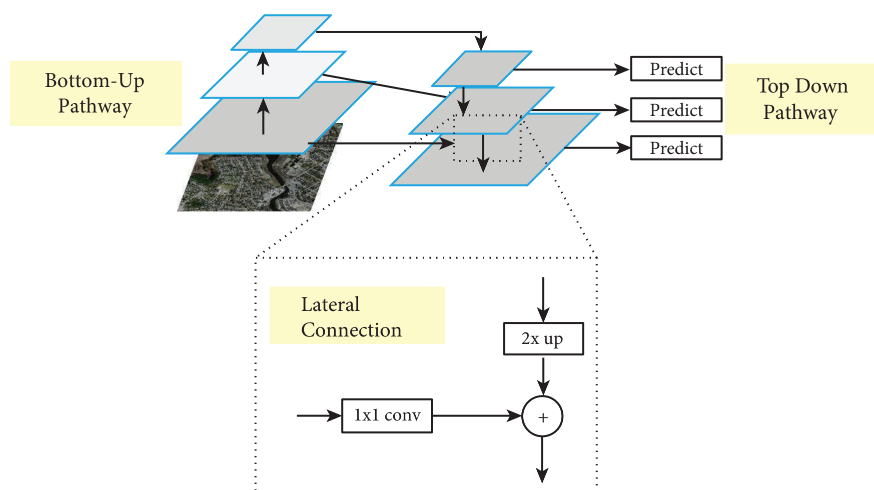

Figure 6: An illustration of the FPN architecture.

network at the higher level. Assuming that the input to a neural network segment is X and the desired output is $H(X)$, the shortcut converts the original learning target $H(X)$ to $H(X)-X$ so that the whole network needs to learn a portion of the difference between the output and the input, simplifying the target and the difficulty of learning the network.

3.3.3. DenseNet as Backbone. Based on the ResNet network, Huang et al. [34] proposed a DenseNet model that connects each layer of the network to all previous layers in a feed-forward way while designing each layer to be particularly narrow and learning very few feature maps to reduce redundancy, which achieves accuracy comparable to ResNet on ImageNet but requires much fewer parameters.

3.3.4. Xception as Backbone. With a separable depthwise convolution, Xception replaces the inception modules [35] and adds residual links. This type of approach considerably, without changing the number of parameters, reduces the use of resources during the matrix calculation.

Usually, the encoder structures in segmentation tasks are similar, mainly derived from the network structures used for classification tasks. This has the advantage that the weighting

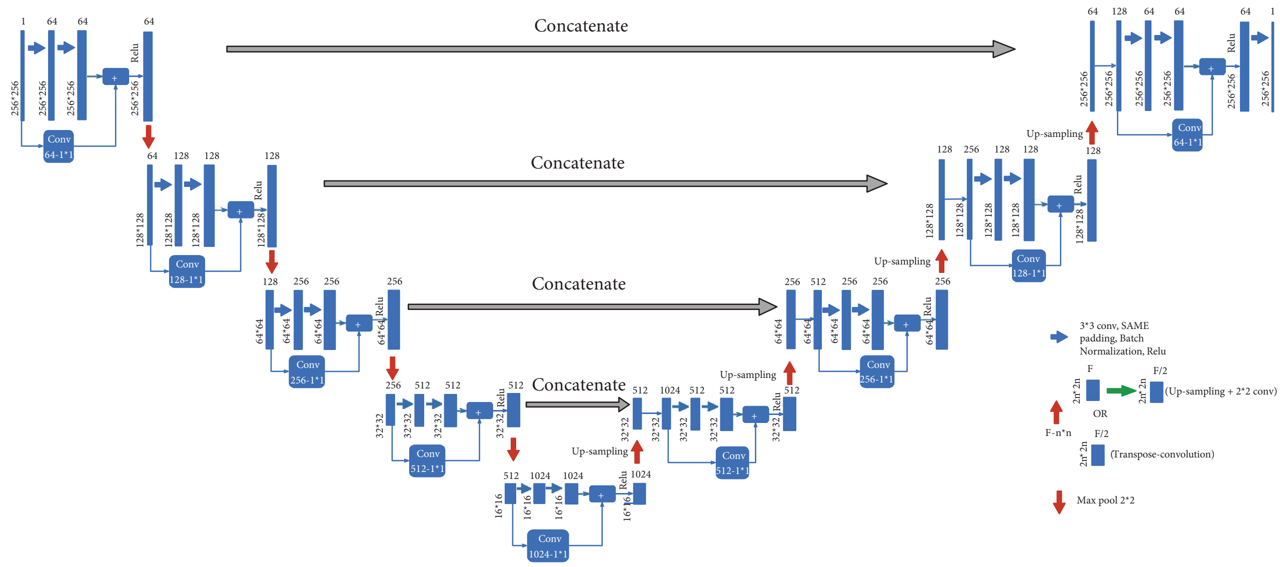

Figure 7: An illustration of the U-Net model with ResNet backbone.

parameters of the classification network trained in the large database can be borrowed to achieve better results through transfer learning. Therefore, the decoder difference largely determines the effect of a segmentation network based on the encoder-decoder structure.

An example of the Res-U-Net (U-Net model with ResNet backbone) is shown in Figure 7.

3.4. Dice Loss Function. The cross-entropy loss function (equation (1)) is often used in binary image segmentation problems. The improvement of cross-entropy is that it is easy to calculate the gradient, but when used in the building extraction problem, it will focus more on identifying the categories with high proportion due to the imbalance of samples, making it difficult to extract categories with few samples. After statistics, the ratio of building to non-building pixels in the Massachusetts dataset is about 1 : 10. To solve this problem, this study chooses the dice loss function to complement the cross-entropy loss function to reduce in building extraction the impact of sample imbalance, which is defined as equation (2),

$$L_1 = -\sum_{n=1}^{N} \left(y_n' \log y_n + (1 - y_n')\log(1 - y_n) \right), \quad (1)$$

where y_n' represents the true label class, building pixels are 1, non-building are 0, $y_n \in [0, 1]$ represents the predicted class probability, N is the total number of pixels in a sample, and n is one of the pixels,

$$L_2 = 1 - \frac{2\sum_{n=1}^{N} p_n \times t_n}{\sum_{n=1}^{N} p_n + \sum_{n=1}^{N} t_n}, \quad (2)$$

$$L_3 = L_1 + L_2, \quad (3)$$

where p_n and t_n represent the predicted category and the true label category of the pixel, respectively, and the rest of the parameters are defined in the same way as in formula (1).

According to equations (1) and (2), when there are too many non-building pixels, the cross-entropy function will make the network tend to reinforce the learning of non-building and increase the predicted category probability of non-building pixels to reduce the loss. In contrast, the dice loss function only focuses on the correct classification of the building pixels. Therefore, in this study, the dice loss function $L1$ (equation (1)) and the cross-entropy loss function $L2$ (equation (2)) are added to obtain a composite loss function $L3$ (equation (3)) that combines dice and cross-entropy, which improves the performance of the network classification ability when buildings have few pixels.

4. Experiments and Analysis

4.1. Data Description. The Massachusetts dataset, created by Mnih [36], was captured in Massachusetts, USA, and contains labels for buildings and roads, which were used in this experiment only for building extraction. The dataset contains 137 training images, 10 test images, and 4 validation images, with 3 bands of red, green, and blue, all 1500 pixels in length and width, and a spatial resolution of 1 m, covering an area of approximately 340 km^2. As mentioned in Figure 8, an original RGB image with its validation mask whose objects (buildings in this case) are shown in binary.

4.2. Data Augmentation. In general, the larger the amount of data, the more easily the model can learn representative features. Due to the high cost of acquiring new data, there are various data enhancement techniques to increase the amount of data, such as zooming in, zooming out, rotating, flipping, color changes, etc. In this experiment, zooming, rotating, and horizontal and vertical flips were used to enhance the data. Figure 9 depicts the results: Figures 9(a) and 9(b) show the original raw image and the modified image, respectively.

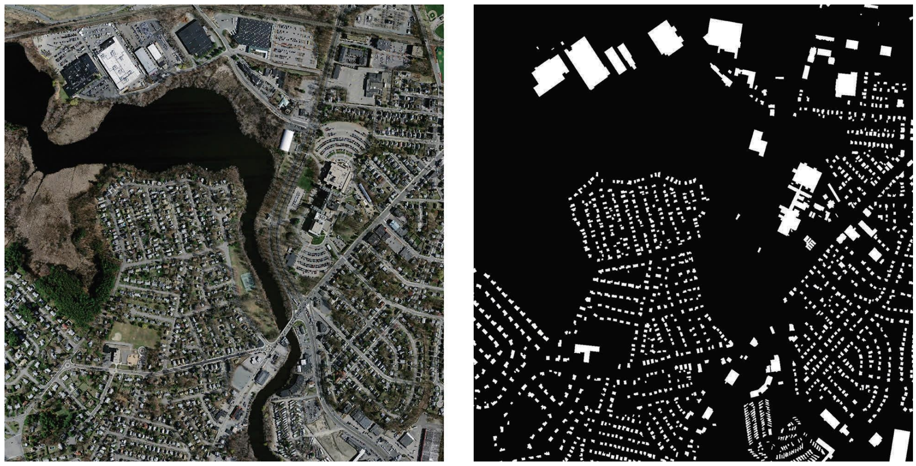

Figure 8: An example of the original and ground truth mask of testing Massachusetts buildings' dataset.

4.3. Implementation Details. The internal parameters of the neural network can be obtained by iterating the optimization algorithm, while some hyperparameters need to be set artificially to guide the model during learning, such as learning rate, optimization function, weight decay parameter, etc.

The optimization problem is one of the most important research directions in computational mathematics. In the field of deep learning, the choice of the optimization algorithm is also the top priority of a model. The Adam optimization [37] function was used in this paper; it is one of the most popular optimizers in deep learning. It is suitable for many types of problems, including models with sparse or noisy gradients. Its ease of fine-tuning makes it possible to achieve good results quickly. The Adam optimizer combines the advantages of AdaGrad and RMSProp. Adam uses the same learning rate for each parameter and adapts independently as learning progresses.

The learning rate is considered as one of the essential hyperparameters for optimizing deep neural networks; by acting on its convergence, it sets the conditions of its operation before the learning process. Indeed, a too high learning rate leads to essential weight updates, and the convergence becomes unstable. On the other hand, for a low learning rate, the convergence is slowed down with a possibility of falling into local minima. The popular approach used in deep learning to have the optimal learning rate is to start learning with a high value to accelerate the gradient descent and reduce it later to improve the accuracy [38]. Practically, this involves initializing an $\alpha 0$ to a high value at the beginning and then decreasing it by a constant multiplicative factor during the learning phase until the validation error reaches a stable value or when the learning error does not decrease anymore [39].

The initial learning rate was 0.0001; it could be formulated as in equation (4),

$$lr = 0.0001 \times \left(1 - \frac{iter}{\max iter}\right)^{0.9}. \tag{4}$$

In our experiments, the training and testing process for building detection was implemented in the PyTorch framework using the Nvidia TesUla K80 graphics card. The batch size was 16 with 100 epochs.

4.4. Evaluation Metrics. To validate the semantic segmentation performance of the proposed method, in this paper, we use four indicators (precision, recall, F1 score, and IoU (intersection over union)) to evaluate the performance of different methods on the dataset. The IoU indicator is, often referred to as the intersection over union ratio, also known as the Jaccard index, and it is a statistic for determining how accurate an object detector is on a given dataset, which is often used not only in semantic segmentation evaluation but is frequently used in object detection problems, such as remote sensing images. As the name suggests, IoU is the ratio of intersection and union between the target and the prediction (equation (5)),

$$J(A, B) = \frac{|A \cap B|}{|A \cup B|} = \frac{A \cap B|}{|A| + |B| - |A \cap B|}, \tag{5}$$

where A represents the buildings and characteristics predicted by different methods and B represents the map of the actual characteristics of the building.

The precision is expressed as the ratio of the number of correctly predicted positive samples to the number of all predicted positive samples,

$$Precision = \frac{TP}{TP + FP}. \tag{6}$$

The recall is expressed as the ratio of the number of correctly predicted positive samples to the number of all positive samples in the test set,

$$Recall = \frac{TP}{TP + FN}. \tag{7}$$

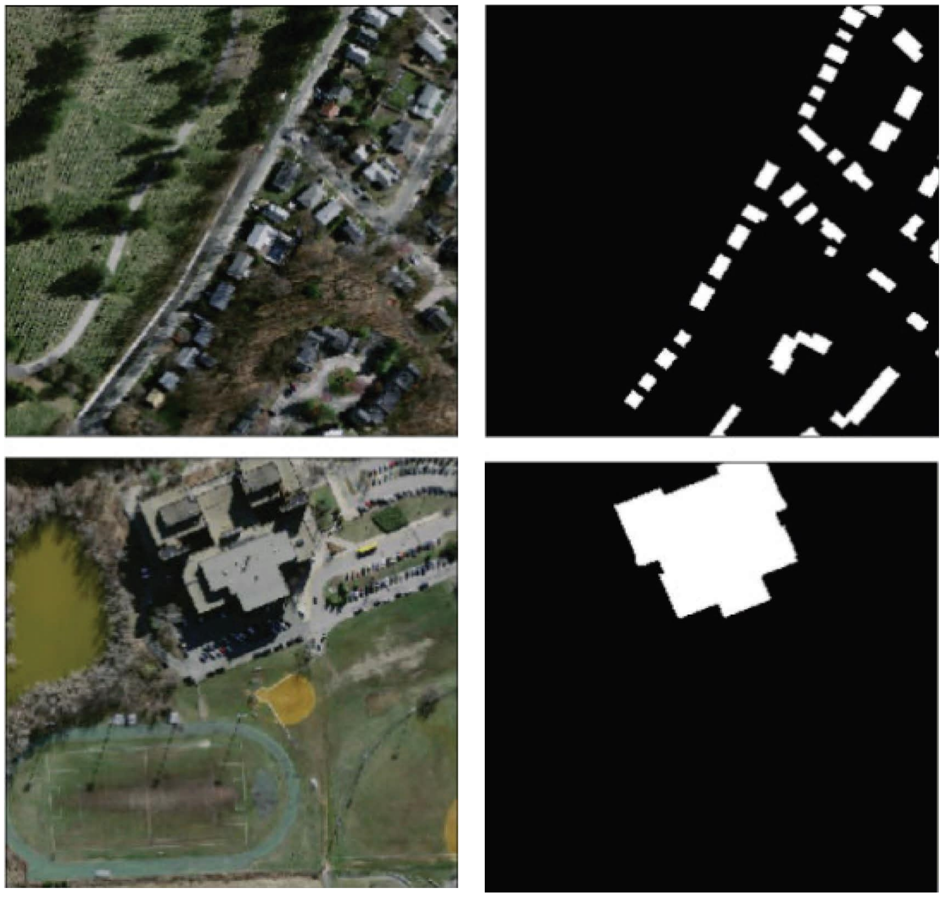

FIGURE 9: Examples of data augmentation pre-processing. (a) Transform image and (b) transform ground truth mask.

F1score is the geometric mean between precision and recall, also known as the harmonic mean, and is an index to measure the precision of the binary classification model,

$$F1\ score = \frac{2 * Precision * Recall}{Precision + Recall}, \tag{8}$$

where TP (true positive) refers to the number of correctly classified positive samples, FP (false positive) refers to the number of negative samples mislabeled as positive samples), TN (True Negative) refers to the number of correctly classified negative samples), and FN (False Negative) refers to the number of positive samples incorrectly marked as negative samples).

5. Results

The proposed networks are built with deeper encoding and decoding layers to achieve better building segmentation results. The FCN method uses a simple convolutional coding layer. Due to its low encoding and decoding layers, it cannot fully extract the variable features from the building features, which leads to poor building feature extraction results.

This research undertakes five experiments based on VGG16, VGG19, ResNet50, DenseNet169, and Xception as a backbone for comparative analysis to demonstrate the relevance of the depth of encoder and decoder layers in building the network for each model. In this work, the efficiency of several deep learning-based models (U-Net, FPN, PSPNet, and LinkNet) in extracting buildings from high-resolution aerial images was evaluated, and in this case, IoU technique, Fscore, precision, and recall were implemented and used. Each of these models may offer several distinct advantages over the others. For example, the U-Net with VGG16 is a shallower model than others and has a basic network topology. On the other hand, PSPNET architecture considers the image's global context when predicting local level predictions, resulting in improved performance on benchmark datasets such as cityscapes and PASCAL VOC 2012.

Because the buildings in each region have various distribution characteristics, and it is difficult for each approach to reach a full optimum impact in different locations, the results of FPN in the test set are not as excellent as the other techniques, as shown in Table 1, but U-Net with VGG16 surpasses all other methods in IoU at the same time. Second, we have LinkNet, which is always using the VGG16 decoder, followed by VGG19, which outperforms U-Net in recall and has an interesting Fscore that is very near top model. Based on this first IoU comparison, we may infer that the U-Net and LinkNet classifiers perfectly match the VGG decoder.

Table 1: Comparison metrics of the models tested in this study.

Model	Encoder	IOU	$F1$-score	Precision	Recall
PSPNet	VGG16	0.7784	0.8743	0.8405	0.911
	VGG19	0.7772	0.8735	0.8426	0.9068
	ResNet50	0.7176	0.8452	0.8261	0.8653
	DenseNet169	0.6669	0.7946	0.7762	0.8139
	Xception	0.6528	0.7844	0.7566	0.8144
LinkNet	VGG16	0.8179	0.8992	0.8585	0.9439
	VGG19	0.8193	0.9001	0.8568	**0.9481**
	ResNet50	0.82	0.9003	0.8671	0.9363
	DenseNet169	**0.8238**	**0.9027**	**0.8808**	0.9256
	Xception	0.8127	0.8959	0.8715	0.9216
FPN	VGG16	0.6952	0.7681	0.7403	0.7981
	VGG19	0.6812	0.7528	0.7252	0.7826
	ResNet50	0.6656	0.7481	0.7255	0.7721
	DenseNet169	0.6632	0.7476	0.7288	0.7673
	Xception	0.6471	0.7336	0.7120	0.7567
U-Net	VGG16	**0.8302**	**0.9067**	**0.8846**	0.9298
	VGG19	0.8296	0.9064	0.8827	0.9314
	ResNet50	0.8233	0.9023	0.8741	0.9324
	DenseNet169	0.826	0.9041	0.8788	0.931
	Xception	0.821	0.901	0.8782	0.925

Table 2: Comparison table between three other models using IoU metric.

Model	IoU
MHA-Net [41]	0.7446
ABNet [40]	0.8165
U-Net + ResNet50 [42]	0.8263
U-Net + VGG16	**0.8302**

Second best Fscore is for LinkNet with the DenseNet169 encoder, followed by ResNet50.

Table 2 compares the test data to numerous novel segmentation approaches reported on the aerial image dataset in the previous two years. When compared to the AttentionBuildNet (ABNet) model provided in [40], our findings suggest that the U-Net approach with VGG increases the IoU by 1.73 percent. A second comparison is with the MHA-NET models provided by [41], in which our model has a UoI of 11.5 percent, a significant improvement over the MHA-NET models. When compared to the Res-U-Net approach described in [42], VGG U-Net improves IoU by 0.52 percent [42].

Figure 10 depicts the experimental visualization, where Figure 10(a) is the original image of the data set in the Massachusetts region and Figure 10(b) is the original image labelling. Figures 10(c)–10(e) illustrate the best possible outcomes of each model, PspNet, LinkNet, and U-Net (e). In comparison to the segmentation findings, the prediction results show that the U-Net technique in this study can better differentiate the borders between buildings, create fewer misclassified pixels with less loss of edge information, and capture crisper features. It can produce a more precise and realistic extraction. A well-defined segmentation enables for better categorizing of the sought objects. The findings of the proposed model were fascinating for both high and low density areas.

There are several types of buildings (large shopping mall, residential, industrial, etc.), and as shown in Figure 11, U-Net can better distinguish the large buildings with a high accuracy compared to PspNet, which finds much difficult to extract them better. This is due to the structure of the building, which has a remarkable similarity to the parking lots. However, with a simple building structure, as shown in the first row of Figure 11, most models are also closer to the ground truth. Solar shadows on the building itself can influence the building extraction too much. The results of building segmentation in a large area can reflect the degree of model training, as shown in Figure 12. It can be seen from the segmentation results that neither of the two-deep neural networks (PspNet and LinkNet) can fully achieve accurate building segmentation, which indicates that there is still a gap between the trained model and the actual segmentation model. On the other hand, we can see that Figure 12 confirms even more that U-Net with vgg16 distinguishes buildings better and can adapt to different types of high resolution remote sensing images. Furthermore, we can see that U-Net with vgg16 represents less False Negative than the other models and less False Positive due to the shadow caused by the buildings, which represents a significant challenge to increase the accuracy.

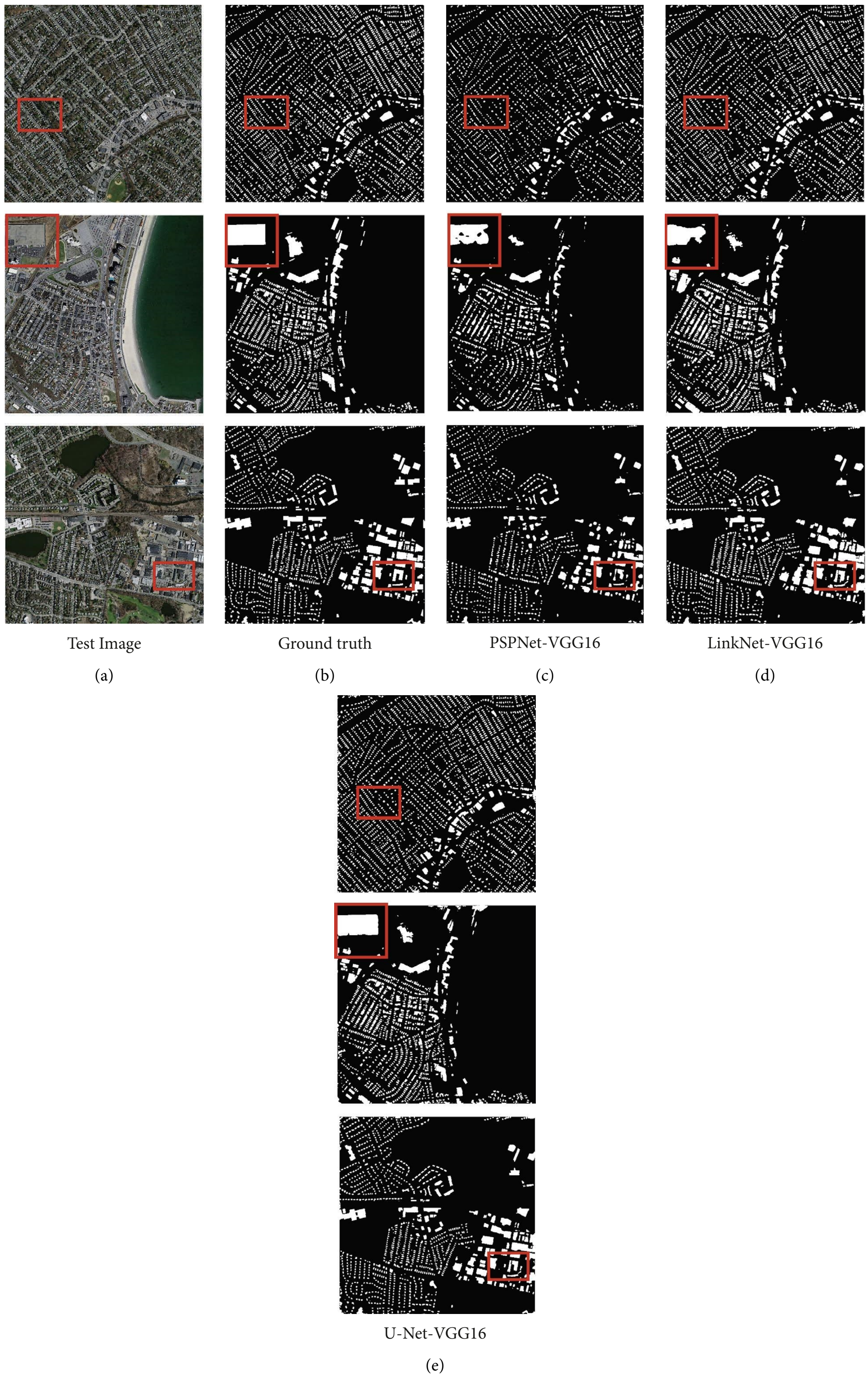

FIGURE 10: Examples of the extracted results on the Massachusetts building dataset. (a) Test image, (b) ground truth, (c) PSPNet-VGG16, (d) LinkNet-VGG16, and (e) U-Net-VGG16.

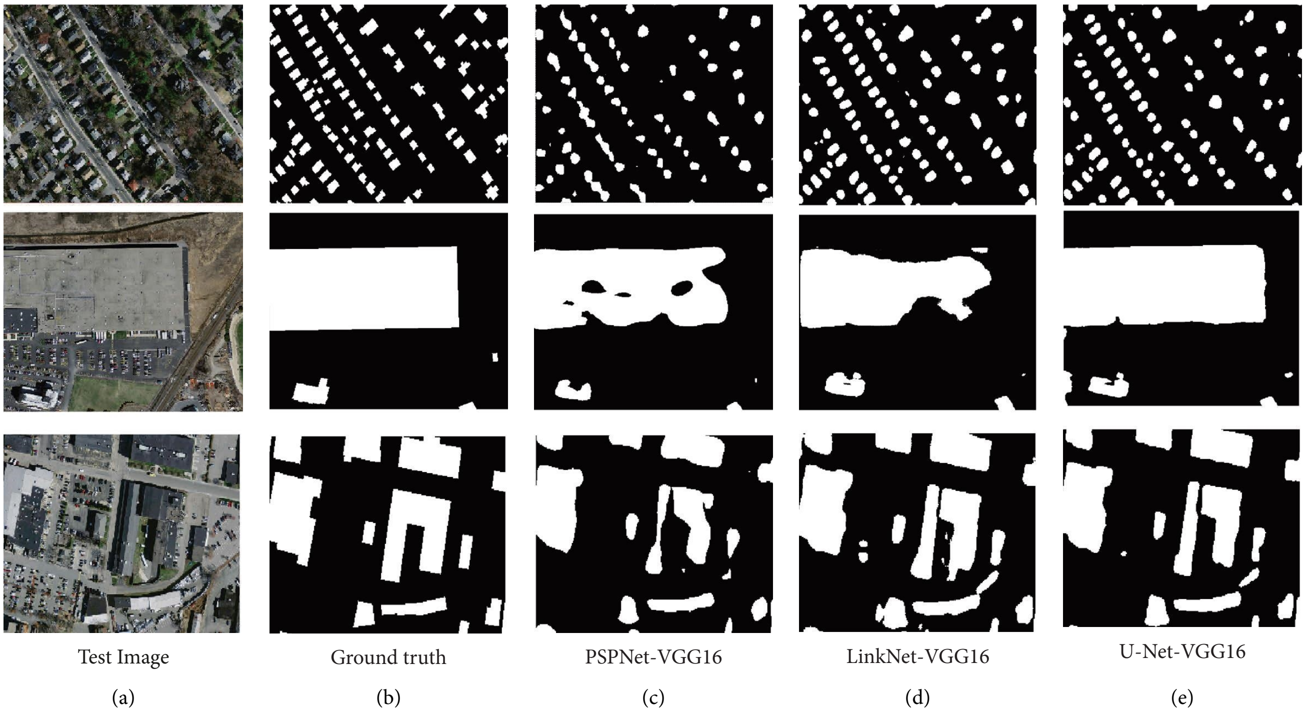

Figure 11: Performance comparison of building with different textures. (a) Test image, (b) ground truth, (c) PSPNet-VGG16, (d) LinkNet-VGG16, and (e) U-Net-VGG16.

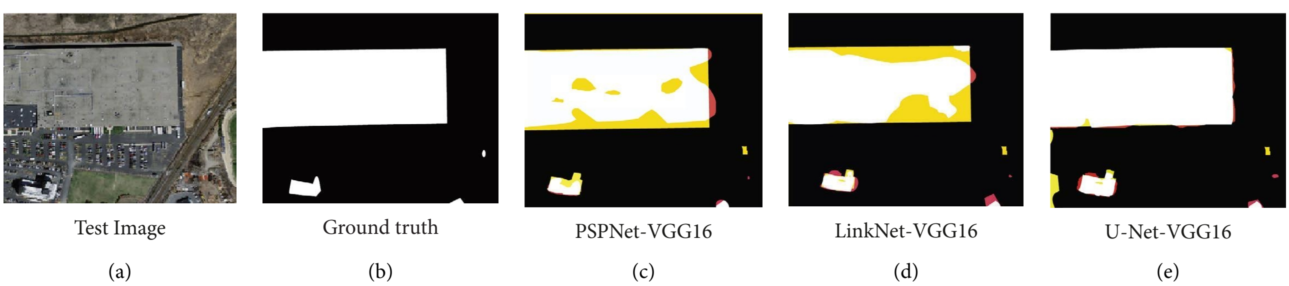

Figure 12: Visual comparisons. White = TP (the predicted result is a building, and the ground truth is also a building), black = TN (the ground truth is a non-building, and the predicted result is a non-building), yellow = FN (the ground truth is a building, and the predicted result is a non-building), and red = FP (the ground truth is a non-building, but the predicted result is a building). (a) Test image, (b) ground truth, (c) PSPNet-VGG16, (d) LinkNet-VGG16, and (e) U-Net-VGG16.

6. Conclusions

Building segmentation from remote sensing images must be accurate and automated for applications such as urban planning and catastrophe management. The current state of development of key deep learning approaches for image categorization and building instance extraction from high-resolution remote sensing images is discussed. Furthermore, this paper mainly focuses on the four most advanced autoencoder methods U-Net, PSPNet, LinkNet, and FPN, with an improvement of the models using VGG, ResNet, DenseNet, and Xception as backbone. The feature similarity of different pixel types was weakened to effectively separate pixels from urban and complex background areas. Considering that existing classical image classification methods based on deep learning have many limitations, such as generating blurred edges and losing detailed information. Since environmental information and building information are easily confused, which leads to mediocre extraction results, a new loss function is proposed, which allows the model to update the parameters faster and more stably. Training and testing are performed on the Massachusetts aerial image dataset with a coverage of 340 km^2. The results show that the U-net model with VGG16 as backbone achieves the best result with 83.06%, where it outperforms all presented models.

In addition, the presence of solar shadows, occlusions, and differences in the characteristics of the building itself will have some impact on the integrity of the building extraction. It is not exhaustive to consider only the color or brightness characteristics of the pixel itself and its local area. In future work, it is necessary to study the shadows and occlusions of buildings in the image to improve the building extraction effect.

Data Availability

The Mssachusetts Building data used to support the findings of this study are available at https://www.cs.toronto.edu/~vmnih/data/.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Construction of Mental Health Education Model for College Students Based on Fine-Grained Parallel Computing Programming

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Psychological education is beneficial in maintaining the psychological health of college students, resolving psychological issues, and creating a harmonious campus and society. Mental health education for college students is a development-oriented basic education activity that contributes significantly to educational quality. To improve the accuracy of college students' mental health assessments, a model for mental health education for college students based on fine-grained parallel computing programming is proposed. This study uses a deep learning algorithm to subdivide the classification of an emotion dictionary, which can be classified by adding negative word lists, polarity conversion dictionaries, and online dictionaries, among other things, based on the theory of ecological instantaneous evaluation. It can be used for both multiclass and detailed emotion analysis. The model is more accurate in assessing the mental health of college students, according to the results of the study. The current emotional state of users can be identified, as well as signs of psychological risk, using emotional analysis of Weibo data, which will become a valuable resource for users seeking clinical psychological consultation in the future.

1. Introduction

From the relationship between college students' psychological quality and ideological and moral quality, good psychological quality is helpful to the formation and consolidation of good moral character. The psychological quality of college students is not perfect; their cognitive level is superficial and one-sided; their emotional will is defective; their personality development is clearly unbalanced; and their ideological and moral progress is hampered [1]. Paying attention to college students' mental health, creates and improves a relevant system for college students' psychological crisis intervention, tracks college students' mental health status in real time, and intervenes in college students who are experiencing a psychological crisis. College students, as social beings, must interact with others and rely on the support of their families, schools, and society [2, 3]. As a result, social support is crucial in college students' mental health education. Colleges and universities should prioritize assisting college students in developing a strong social support system as part of the process of strengthening and improving their mental health education.

At present, the traditional mental health assessment is mainly based on self-assessment questionnaires and structured interviews [4], and data and information are obtained from the assessed through interpersonal interaction, so as to assess the mental health status of the assessed. Although this traditional mental health evaluation method subjectively grasps the mental health status of the subjects from the scale point of view, there is a deviation of social expectation response in the implementation process and evaluation tasks [5, 6], and the evaluation is not good [7, 8]. Some researchers have begun to apply ecological transient assessment theory and social network data to mental health assessment tasks. Methods Data labels are marked by expert analysis or self-rating scale, data sets are formed, data features are extracted [9], and models are trained to realize the automatic assessment of mental health [10, 11]. The traditional mental health education model is mainly based on teachers' "teaching". This model turns the training process into a simple "knowledge inheritance" process. Although students can master the system, they master solid psychological theories and concepts, but ignore this model. Let students learn independently. Even in some universities that use the Internet for mental health education, the form is too simple and the effect is not ideal.

With the advent of the "Internet plus" era, new technologies represented by artificial intelligence are gradually reshaping the education service system and opening the closed door of existing education [12, 13]. Interaction with network education is common, which opens up new possibilities for university mental health education development. Some universities are forming three- to four-level mental health education networks, such as school-based counseling centers for college students' mental health education, undergraduate and faculty mental health education workstations, and college student mutual aid associations. A model of mental health education for college students is proposed in this paper, which is based on fine-grained parallel computing programming and includes a concrete action plan and implementation scheme.

This paper studies and innovates the aforementioned problems from the following aspects:

(1) We propose an evaluation model of college students' mental health based on multimodal data fusion. Maximum rule is used to fuse and calculate multimodal data, and latent conditional random field algorithm is used to accurately evaluate the mental health level of individuals, taking into account the psychological changes of students in a specific period of time.

(2) Constructing psychological early warning model based on granular emotional dictionary. It uses the change of user's emotional state as the result display output, and makes early warning analysis of psychological crisis events by screening the signs of psychological crisis.

The paper is divided into five parts, and the organizational structure is as follows: Section 1 introduces the research background and current situation of college students' mental health education, and puts forward and summarizes the main tasks of this paper. Section 2 introduces the theoretical basis of college students' mental health education research. Section 3 introduces the realization of college students' mental health education model based on fine-grained parallel computing programming. Section 4 compares the performance of this model through experiments. Section 5 is the full-text summary.

2. Related Work

2.1. Research Status and Development Trend of College Students' Mental Health Education. Tao believes that mental health is a lasting psychological state in which a person can adapt well, have vitality and give full play to his physical and mental potential [14]. This is not only a relief from mental illness but also a condition for active prosperity. Eisenberg believes that mental health should include three aspects: normal mental state, harmonious interpersonal relationship, and complete social adaptation [15]. Wang et al. [16] proposed 10 standard levels of circadian rhythm consciousness, which represent psychological activity intensity, psychological activity tolerance, psychological rehabilitation ability, psychological self-control, self-confidence, and social interaction environment adaptability. This paper summarizes the contents of mental health education from many dimensions, such as emotion regulation and will exercise, in order to better carry out mental health education, promote mental health education, and lay a good foundation for the development of students' mental health from the perspective of comprehensiveness, balance, and development of college students' mental health education. By synthesizing the experience and lessons of predecessors, Mc and others summarized the contents such as holding lectures, strengthening public relations, conducting a health survey, improving the network education system, and actively advocating self-education. In the network age, the network education system and curriculum education methods are quite extensive [17]. Zhang examined the significance of mental health education for college students and discussed the specific working mechanism as a result [18]. According to Gong, mental health is the key connotation of life growth and plays a critical role in students' life growth, and the meaning of life also plays a significant role in maintaining and developing college students' mental health [19]. In the end, the meaning of life and mental health are complementary, which is critical for a thorough examination of college students' mental health education.

Many domestic researchers have conducted in-depth research on the effect of college students' mental health education, showing the characteristics of various methods and in-depth contents. Meng et al.'s research results show that 84% of college students like the teaching methods of mental health courses [20], while Yu et al.'s research results show that mental health education plays an important role in improving mental health, and college students and other educational methods have different effects [21]. The research results of Xin et al. show that mental health education is an effective way to improve the mental health of ethnic minority college students [22]. Li tracked the mental health of 449 students for 2 years and found that mental health education can significantly improve students' mental health. The most effective method of mental health education is psychological lecture [23].

The content, methods, and methods of personnel training, among which the specific methods of personnel training are the most prominent, will be the most important topics in future research on college students' mental health education. The following are the different types of mental health education training available in universities. We established a specialty devoted to cultivating college students' mental health education practitioners, improving the systematization and standardization level of personnel training, and laying a solid foundation for the school's long-term development, starting with the school's own orientation and educational resources. Students should be given mental health education.

2.2. Research on Fine-Grained Parallel Computing Programming. Thread-level speculation technology on general-purpose processors can take advantage of granular parallelism, fine-grained operations correspond to threads on general-purpose processors, and task creation and allocation are managed by the runtime system as a thread pool. Xian has invested a lot of money in developing new general-purpose CPUs, which combine reconfigurable computing technology [24] with Intel X86 architecture and apply reconfigurable computing to information security chips and cryptographic chips.

Paji et al. put forward a new programming model, which allows programmers to declare applications as a group of tasks that can be executed in parallel, and describe the dependencies between tasks as Promise [25]. Then, the concurrent tasks are automatically mapped to reconfigurable computing resources in the airspace for execution. This technology effectively makes use of fine-grained pipeline-level parallelism in applications. Kashi et al. designed a pipeline processing unit and interconnection network architecture, which includes coarse-grained and fine-grained data paths, encapsulated these architectural features as an execution mechanism, and provided a compiler to allow programmers to write programs for reconfigurable processors. Use complex control flow and advanced programming tools to create high-performance applications [26]. Liu et al. designed a programmable register shared by several reconfigurable arrays and provided it to programmers as a programming method. When programmers write programs for reconfigurable processors, they can choose the stream processing mode or the private mode of the register according to the characteristics of the application.

3. Methodology

3.1. Construction of the Theoretical Model of Influencing Factors of College Students' Mental Health. Mental health education for college students is a systematic project of cooperation among schools, families, and society [9]. College students' mental health education aims to help educators to cultivate students' good psychological quality and improve their psychological quality using the theories and technologies of psychology, pedagogy, and even psychiatry according to the characteristics of college students' physiological and psychological development. Psychological function can bring students' full potential into play, and promote the overall improvement of students' comprehensive quality and individual harmonious development of students' education.

Human ideology is not static; it evolves in response to changes in social practice. The shift in ideological activities is particularly noticeable during periods of active social change. The ebb and flow of ideological activities among today's college students is also consistent with the era's characteristics. Young college students are under a lot of psychological and emotional pressure as a result of the transitional period's social and economic development, and they are prone to strong emotions like loneliness and anxiety. Preventive education is required in psychological education in order to improve college students' self-defense awareness and survival skills, improve their psychological quality, guard against potential risk factors, and improve the quality of education in order to provide scientific and effective psychological intervention for students with problems.

Various functional elements in the individual psychological adaptation system, including defense mechanism, are constantly influenced by the ecological and cultural background and family upbringing in the process of individual development and gradually form the psychological characteristic structure with specific cultural background and cultural value and the formation of culture-oriented laws and regulations.

Families also pass on the physiological characteristics formed in the process of biological adaptation to the next generation through genetic methods, forming specific physiological and functional characteristics of specific countries. In the process of psychological adaptation to environmental input and output, the defense mechanism system in turn affects the entropy state of the psychological adaptation system, and then affects the mental health state. Their specific relationship is shown in Figure 1.

Many studies have shown that the use of negative psychological defense mechanism will decrease with the increase of individual interpersonal emotion, interpersonal atmosphere, and positive sense of life goal value. The psychological living space of college students includes not only the past and present frame of reference, but also the future trend reference. Correspondingly, adaptation always occurs under different psychological space-time standards, and there are differences in the sources of psychological space-time, so information processing and behavior supervision can have different time schedules.

College students' mental health education is not limited to solving a few students' psychological problems, but also to comprehensively improve students' psychological quality and promote their healthy growth and success. Healthy personality and good personality will enable students to fully tap their psychological potential, continuously improve their competitiveness and strive to realize their self-worth.

3.2. Mental Health Assessment. Mental health is a harmonious state of individual psychological function balance, and the most common abnormal state of mental health is anxiety and depression [1]. College students are in the transition period between campus and society, under the pressure from all sides, and are prone to expose various psychological problems, among which depression is particularly prominent [20].

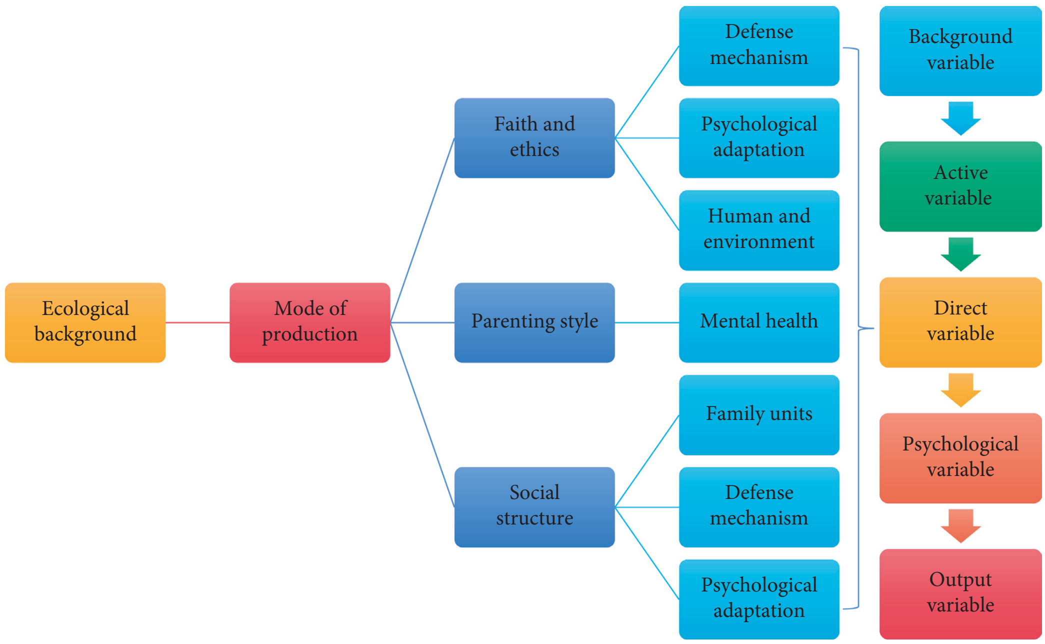

Figure 1: Formation mechanism of mental health status.

People require a sense of belonging, but a lack of belonging frequently leads to mental illness, and positive interpersonal relationships are critical in preventing psychological issues. Counselors and teachers make up the majority of the school administration. Their job is to look after every student, especially introverted students, by anticipating their needs, communicating care and love to them, and preventing emotional and relational support. Mastering all scientific and cultural knowledge requires a strong psychological foundation. Slow thinking, a lack of interest and motivation to learn, and a lack of understanding of basic learning methods, all of which contribute to low psychological quality, make it difficult to survive in society, let alone for college students involved in complex scientific creation or knowledge innovation activities.

Design the evaluation model of college students' mental health based on big data, in order to obtain ideal diagnosis results of college students' mental health. The cumulative value S_{ikj} of the comparison result between the characteristic word w_{ij} of text T_i and all characteristic words of text T_k is as follows:

$$S_{ikj} = \sum_{r=1}^{r=n_k} S_{ikjr}. \tag{1}$$

There are great differences among the feature words in the same text. There is at most one feature word identical to w_{ij} in the text T_k, so the value of S_{ikj} can only be 0 or 1. It can be obtained that there are the same number of feature words in the text T_i and the text T_k. The formula of S_{ik} is as follows:

$$S_{ik} = \sum_{j=1}^{j=n_i} S_{ikj}. \tag{2}$$

Text similarity is the ratio between the same number of feature words and the smaller T_i, T_k total number of feature words in different texts, and the similarity P_{ik} between text can be obtained as follows:

$$P_{ik} = \frac{S_{ik}}{\min\left(n_i, n_k\right)}. \tag{3}$$

The clustering index scales adaptively, sets a fixed threshold, classifies the texts whose similarity is higher than the threshold into one category, and uses the obtained clustering results as the evaluation index.

Traditional computing systems use an I/O bus to connect functional devices. It is easy to use and powerful, but data transmission between functional units must go through the slow I/O bus. With the increased communication frequency between general-purpose processors and various DSA in the era of DSA (domain-specific architecture), most computing chips turn to SoC to integrate general-purpose processor and DSA. When switching multiple sets of configuration information, the configuration controller and data path must satisfy the control dependency between infinite periods. As a result, the runtime data path frequently waits for the configuration controller to query the status before manually loading the configuration word, reducing the data path's utilization rate.

In order to solve the problem that the complex control flow, especially the variable-length loop, is difficult to be efficiently executed on the reconfigurable data path with limited computing resources, this chapter adds the active loading mechanism of data flow execution based on the dynamic scheduling of the classic dynamic reconfigurable processor. The active load execution mechanism simplifies the design of the compiler and effectively handles the complex control flow shown in Figure 2.

The compiler must determine the execution order of operators for dynamic scheduling and manual loading of reconfigurable processors, so the hardware architecture is represented by the compiler as a two-dimensional table, and

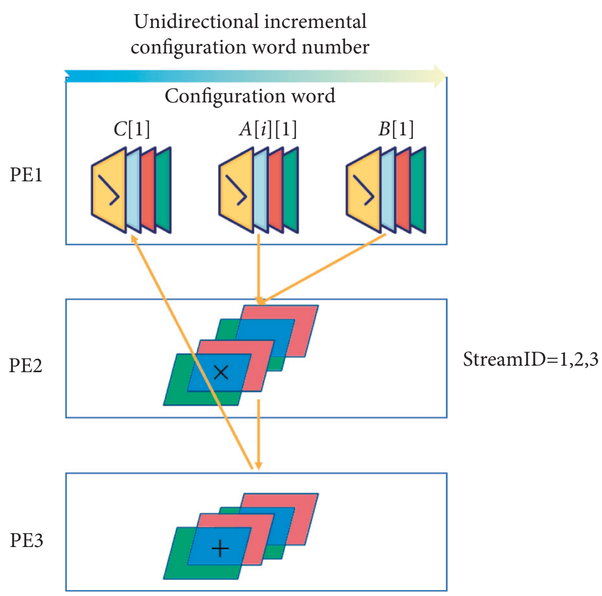

Figure 2: Models of hardware architecture considered by compilers under different execution mechanisms.

the compiler must determine the relative relationship of each operator. The compiler only needs to decide which processing element PE (Processing Element) to execute the operator on in reconfigurable processors with dynamic scheduling and dynamic loading. The processor's hardware architecture is spatially separated, so the compiler does not need to consider the operator. In today's technologically advanced society, college students frequently publish text, images, expressions, and other modal data on social media platforms at the same time to express their thoughts and feelings. Different types of modal data can be combined to provide more descriptive information. A more comprehensive and systematic analysis and evaluation of students' mental health can be achieved by integrating and understanding multimodal data.

The effective fusion of multimodal information is the key problem in multimodal emotion calculation [27]. It uses the maximum rule to calculate the emotional tendency values of text and images, and accurately judges the students' psychological state by fully considering emotional factors. When the specific calculation process is expressed by

$$\begin{aligned} P'_j &= \max_i \left(P_{ij}(n)\right) \quad i = 1, 2,\ j = 1, 2, \\ P_j(n) &= \frac{P'_j(n)}{\sum_j P'_j(n)}. \end{aligned} \tag{4}$$

Among them, i and j are the number of classifiers and categories and $P_j(n)$ is the probability value of the j-type emotion category.

LSTM (long short-term memory) is mainly controlled by three gates that enter and exit the information flow in memory: input gate, forgetting gate, and output gate. The values of these gates can mainly help the network avoid erroneous gradient update.

In LSTM network, the forgetting gate f_t is mainly responsible for what information the network will discard, that is, the forgetting gate will determine how many cell states C_{t-1} of the last moment can be retained in the current cell state C_t, and the gate will read h_{t-1}, x_t and output a value between [0,1] to each C_{t-1}, where 1 means "completely retained" and 0 means "completely discarded".

The formula of the forgetting gate is as follows:

$$f_t = \sigma\left(W_f \cdot [h_{t-1}, x_t] + b_f\right). \tag{5}$$

Here, h_{t-1} represents the output of the LSTM network at the last moment, x_t represents the input of the LSTM network at the current moment, W_f represents the weight matrix of the forgetting gate, b_f represents the bias of the forgetting gate, and qw represents the connection operation.

Feature extraction is performed as convolution operation, and convolution operation in image domain can be regarded as a weighted summation process. Each element of convolution kernel is multiplied by each pixel in this region of the image, and the calculated sum of products is activated by the value of this position in the next feature map.

There is a relationship between the size of convolution kernel and the step size of sliding convolution kernel, and the specific relationship is expressed by formula 1.

$$O_{fmN} = \frac{I_{fmN} - K_{\text{size}}}{K_{\text{stride}}} + 1, \tag{6}$$

where O_{fmN} represents the size of the output feature map, I_{fmN} represents the size of the input feature map, K_{size} represents the size of the convolution kernel, and K_{stride} represents the step size of the convolution kernel sliding.

In this paper, a time-series analysis model based on implicit conditional random field algorithm is proposed, which can dig out the internal development rules of various mental health levels in a period of time and find out the relationship between emotional changes and mental health. The process of mental health assessment model is shown in Figure 3.

3.3. Early Warning Model of College Students' Mental Health.

Owing to the complexity of emotion and the imperfection of research rules, the definition of emotion is not clear up to now. Owing to the universality and complexity of emotions, it is difficult for the computational model represented by hidden Markov model to simulate the change of emotional state. In this paper, emotional modeling is carried out from the perspective of text emotional analysis. Words expressing emotional state are digitized by polarity and intensity, and human virtual emotions are modeled and formalized by mathematical methods, which is convenient for emotional research and analysis.

Owing to the rapid evolution of network words, new network words that do not exist in the emotion dictionary may appear in the process of emotion analysis. Use so-PMI (sentiment orientation-point wise mutual information) method to calculate the semantic similarity between words, and then obtain the weight of new words from the network.

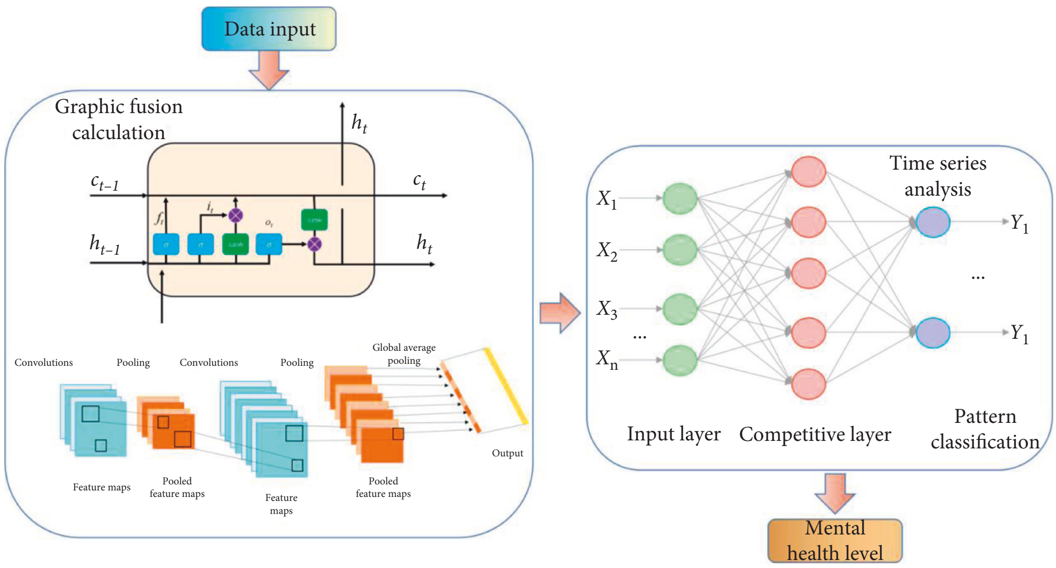

FIGURE 3: Process of the mental health assessment model.

In order to avoid emotional deviation caused by simple addition, the number of evaluation words and the proportion of evaluation words are comprehensively considered, and a more suitable range is obtained through intermediary coefficient. We have

$$W_i(\text{word}) = \sum_j \gamma^{\text{PMI}\left(\text{word},w_{ij}\right)}, \text{SO}(\text{word}) = \max_i (W_i). \quad (7)$$

w_{ij} is the j benchmark word in the i-type emotion category and γ is the mediation coefficient.

Through the aforementioned analysis, this paper proposes an emotion analysis algorithm based on weighting factors, combining the calculation methods of emotional vocabulary weight and modification weight:

$$\text{SO}(S) = \max \sum \alpha^{C_i w_{ij}}. \quad (8)$$

Among them, SO (S) is the emotional tendency value of the sentence S, w_{ij} refers to the emotional value of the ith emotional word w belonging to the emotional category j, C_i refers to the weight factor that modifies the emotional word, α is the mediation coefficient, when $\alpha = 1$ is used, the text tends to be the category with the largest number of emotional words in the sentence, and when $\alpha = 1$ is used, the text tends to the category with the largest emotional intensity in the sentence.

According to the aforementioned analysis, the basic process of psychological early warning is obtained (Figure 4):

(1) Access the Weibo text data in the web page in real time and store it in the local database

(2) Add stop words list to get useful words for tags

(3) Emotional dictionary is used to extract emotional words to minimize the omission of emotional words caused by incomplete rules

(4) The final weight is calculated according to the improved SO-PMI algorithm

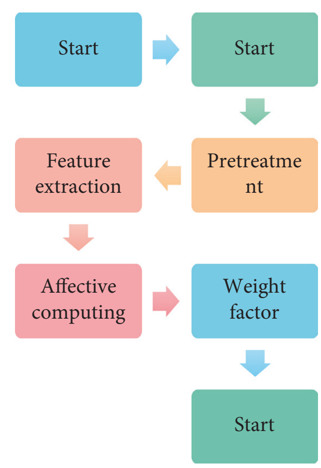

FIGURE 4: Basic process of psychological early warning.

(5) According to the weight-based sentiment analysis algorithm, the sentiment value of the text is calculated and displayed through the sentiment trend graph output

4. Experiment and Results

In order to verify the effectiveness of the proposed evaluation model of college students' mental health, college students were selected as the research object, and questionnaires were distributed to college students through the network. In this paper, the collected questionnaires are clustered to verify the model. Figure 5 shows the statistical results of data processing ability based on Big Data.

It can be seen from Figure 5 that using this model to evaluate college students' mental health can cluster Big Data well from a large number of data, and the model evaluation is accurate. It can be seen from Table 1 that the evaluation results of mental health consistency of college students using this model are all less than 0. It shows that the index system

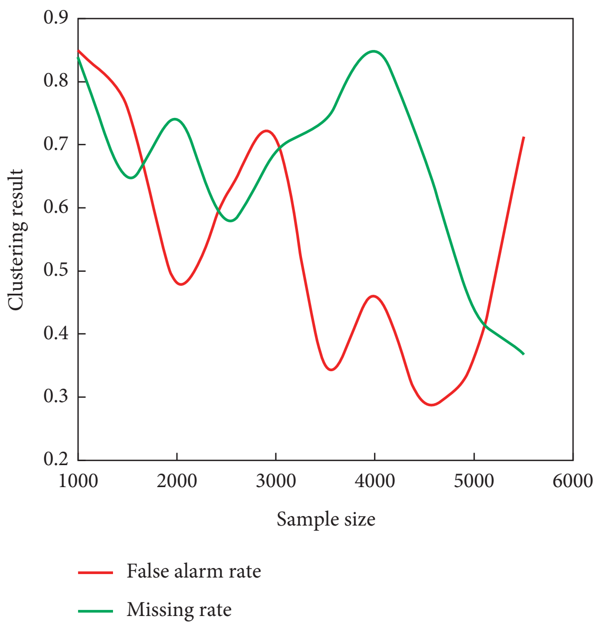

Figure 5: Data clustering result.

Table 1: Consistency judgment result.

Index	Judgment result
Emotion regulation	0.016
Learning influence	0.044
Life influence	0.032
Career influence	0.038

of college students' mental health constructed by this model can meet the judgment requirements and pass the consistency test.

The weight of the evaluation index system of college students' mental health is obtained using this model, and the evaluation results of the first-level index of college students' mental health are shown in Figure 6.

It can be seen that the model in this paper can effectively get the evaluation results of college students' mental health, and find that the overall mental health of college students is in good condition. From the evaluation results, it can be seen that the evaluation results of college students in improving ability, learning strategies, and self-development have low scores.

The accuracy is obtained by comparing the scale scores with the model evaluation results, and the experimental results are shown in Table 2.

Health and depression are at two extremes. In the longitudinal development, health students are mostly in a positive and positive state, while susceptible students continue to be depressed and have a negative attitude towards external stimuli. Therefore, the model can better capture the psychological characteristics of these two categories, and can effectively judge whether students are prone to depression.

Compared with previous studies, this study uses deep learning algorithm to process the network content data, which can obtain deep semantic knowledge and true emotional polarity of modal data such as text and image, and it takes more time to evaluate than traditional machines. The algorithm also has many advantages. By analyzing the content posted by students online in real time, it can quickly judge and continuously track the mental health status of students.

In order to evaluate the impact of active loading mechanism on the performance of specific applications, this study selects five applications with long and variable loops, and manually compiles configuration information from the two execution mechanisms. The evaluation results of the simulator show that after using the active loading execution mechanism, the performance of these five applications is improved by 1.33 times on average compared with passive loading. In order to analyze the reasons for the performance advantages, in this study, we analyzed the cycle-by-cycle execution state of eight PEs on the simulator and obtained Figures 7 and 8.

It can be seen that the time spent by actively loaded PE in configuration and blocking state is obviously less than that in passive state. Further analysis reveals two reasons: as the active loading mechanism does not have to wait for the configuration word sent by the configuration controller, the time of each PE in the blocking state is greatly reduced. The loaded configuration word can still be executed, which reduces the time spent by PE in configuration.

Negative emotions play an important role in psychological crisis intervention, and in psychological counseling, whether the counselor has negative emotions and the duration of negative emotions are important criteria for evaluating the psychological state. The research goal of this paper is to establish an early warning mechanism of psychological crisis and to identify negative emotions through experimental tests and case analysis.

The psychological early warning model of this paper evaluates and tests the negative thoughts of Weibo users. This paper analyzes the user's emotional dynamic tendency by constructing the user's emotional trend chart, which fully reflects the user's psychological reaction and has important reference significance (Figure 9).

The emotional trend chart shows that user 1's negative emotional state is always frequent, and multiple Weibo messages are frequently sent in a short period of time to express strong and concentrated emotions. Negative emotions make up 59% of Weibo texts, and the negative emotions of a single Weibo text can reach −18, drawing the attention of relevant staff. These crises can be avoided if timely and appropriate interventions are implemented. College students are the most active group of Internet users. With the rapid advancement of information technology, the Internet has become an indispensable part of college students' study and life, allowing them to keep up with current events, obtain information, express emotions, and have fun. As a result, establishing a good network position and providing good network mental health education has become a new requirement for the development of college mental health education.

Compared with the traditional mental health education, online mental health education has a unique advantage, that is, college students can receive psychological services at any time through the mental health education website without being limited by time and space. Focus on online tutoring,

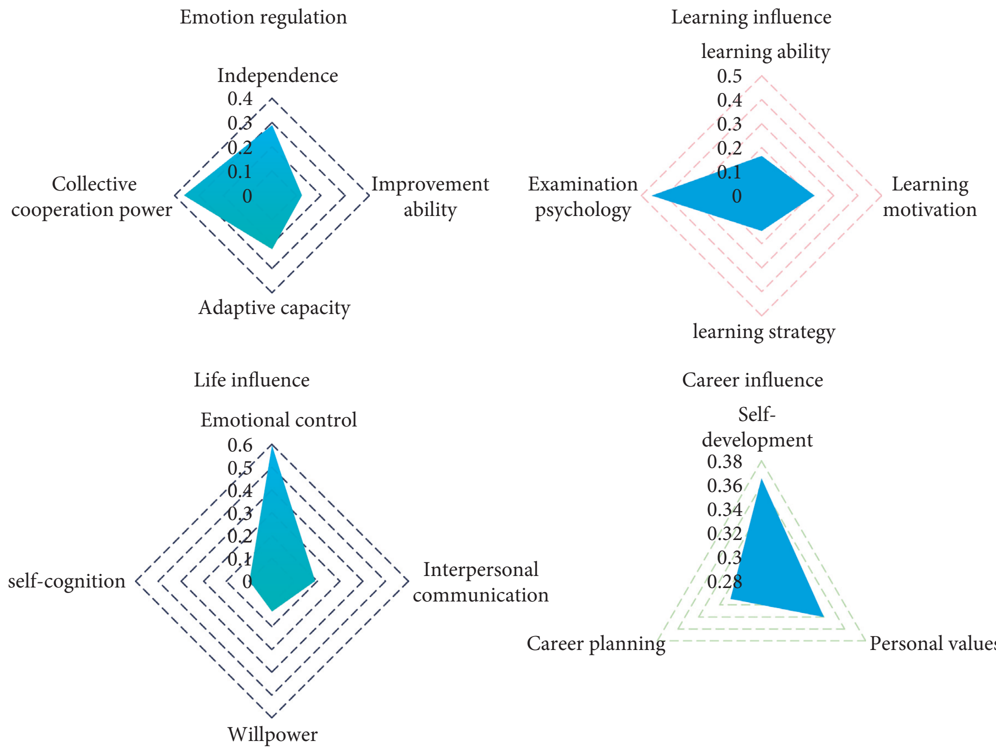

Figure 6: Evaluation results of secondary indicators.

Table 2: Mental health assessment results.

Project	Assessment result (%)
Health	92.14
There may be depression	78.96
Existence of depression	84.57
Average accuracy	84.86

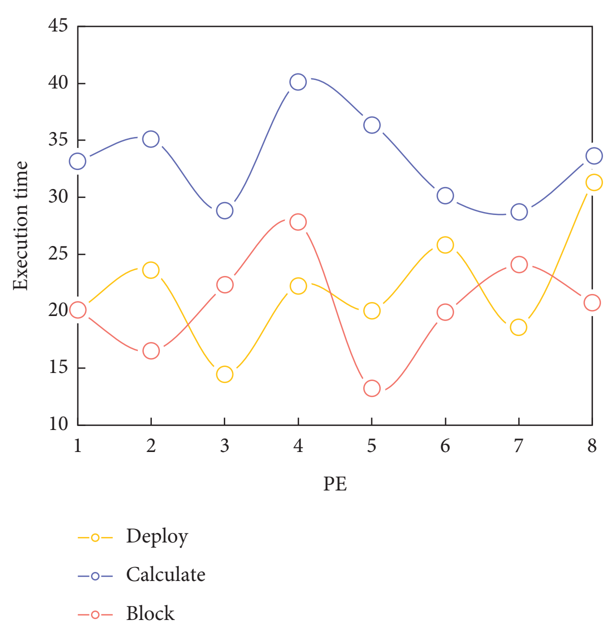

Figure 7: Running state distribution of eight PEs under the passive loading mechanism.

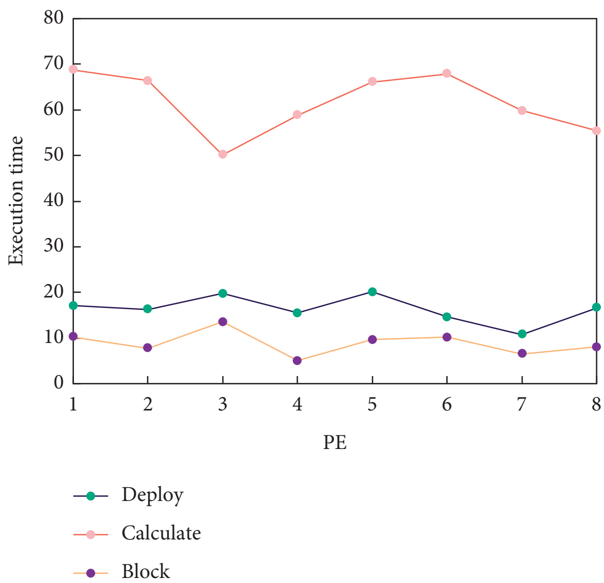

FIGURE 8: Running state distribution of 16 PEs under the active loading mechanism.

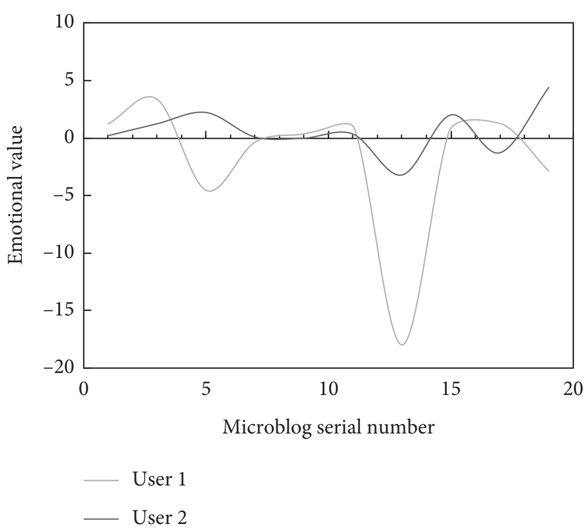

FIGURE 9: User emotion trend.

online communication and discussion, so that confused students can broaden their thinking in time and solve various problems and puzzles in their study and life in time and strengthen the network mental health education team. With the development of network technology, the school will soon cultivate a new type of mental health education team, which will network the psychological dynamics, psychological changes, and psychological needs of college students and provide services and services scientifically.

5. Conclusions

Mental health education for college students is a challenging foundational, systematic, and innovative project. In some ways, this is not only a problem that exam-oriented education has left us with in the past, but also a demand of today's rapidly evolving society. The highly volatile and efficient evaluation model driven by Big Data is useful for addressing college students' mental health issues. The average accuracy rate of a mental health education model created by college students using fine-grained parallel computing programming is 84.86%. The model can effectively reveal the changing trend of students' psychological characteristics if it can accurately understand their mental health status. The accuracy of Chinese emotional analysis can be improved by utilizing bilingual knowledge, including Chinese and English, and constructing a relatively complete and detailed dictionary of emotional norms of Chinese vocabulary. Experiments show that the method proposed in this paper can produce good results, but it still has flaws. In the next step, this paper will investigate the aforementioned aspects in order to develop a more appropriate method in the field of psychological early warning.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares no conflicts of interest.

Acknowledgments

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Research Article

Smart City Public Safety Intelligent Early Warning and Detection

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This study conducts in-depth research and analysis on the intelligent monitoring and early warning of public safety machines in the construction of smart cities, taking risk management theory as the theoretical basis and combining it with the actual situation, i.e., constructing a public safety risk management framework under the background of proposing urban refinement management, a typical case for in-depth analysis, and understanding how the community carries out public safety risk prevention and control through research and interviews and other research methods, mainly including the overall design and the design of application modules for the robot. Based on studying the existing research and combining the advantages of each research method, this study proposes a method suitable for the analysis of this study, which can improve efficiency and accuracy. The robot application module design part, around the system's main emergency command object, i.e., the robot, details its design in four aspects: data communication, situation display, auxiliary decision-making, and command and dispatch. The technical environment for system development is given, the development framework based on BS structure and the development and implementation of data interface modules are detailed, and the development and implementation of the robot application module are explained in detail. Finally, the system functions and performance, and further optimization directions are given based on the analysis of the test results.

1. Introduction

In response to the intricate and complex situation of urban public safety, urban public safety monitoring and management have become more and more complex, and the diagnosis, discovery, and early warning of urban public safety events are difficult to be realized by a single data source and traditional spatial data type; therefore, with the development of the internet, internet of things, social network, and integrated observation system, the process of urban public safety monitoring has been constructed by satellite, UAV, and ground video monitoring [1]. The urban three-dimensional public safety monitoring network is composed of mobile phones and GPS devices. The massive spatiotemporal data generated by urban public safety monitoring mainly include video, image, remote sensing image, vector map, and trajectory data. These data not only contain rich temporal, spatial, and semantic information but also have multidimensional, multiscale, and multitemporal characteristics and multimodal features. The multimodal characteristics of public safety monitoring data make the same spatiotemporal object that may have many different forms of data description, and the different modal data have the characteristics of low-level feature heterogeneity and high-level semantic correlation, in the process of urban public safety diagnosis, discovery, and early warning, and the traditional unimodal data retrieval is far from satisfying the retrieval of different modal data of the same event, how to deeply analyze the connection between the data of different modalities, and how to analyze the data of different modalities? It is necessary to deeply analyze the connection between data of different modes, establish a correlation between data of different modes, and realize efficient cross-modal retrieval of data of different modes of the same event to support accurate, rapid diagnosis, timely detection, and early warning of urban public safety [2]. The core problem of cross-modal retrieval technology is the need to analyze and establish a correlation between data of different modalities, and to achieve cross-modal retrieval between data of different modalities. In recent years, the research on cross-modal retrieval technology for ordinary text, image, and video has been rapidly developing in the computer field, but the research on cross-modal retrieval of multimodal spatiotemporal data with typical spatiotemporal characteristics and rich semantic information is less. With the development of three-dimensional public safety monitoring networks in cities, research on cross-modal retrieval techniques for multimodal public safety monitoring data has become the key to support diagnosis, discovery, and early warning of urban public safety events [3]. Therefore, cross-modal retrieval for urban public safety monitoring data, association construction of multimodal spatiotemporal data, spatiotemporal indexing methods considering spatiotemporal semantics, and cross-modal retrieval methods are the focus of this study.

The concept of urban public safety governance has also emerged. Cities are the most concentrated areas in terms of human and material resources and financial resources and are important representatives of the economic development of a region. As the scale of cities continues to expand and the level of urbanization continues to rise, a variety of urban public safety events pose a great threat to people's lives and safety. From the theoretical point of view, this study combines many research directions based on the discussion of urban public safety risk generation mechanisms with existing theoretical results and key perspectives, such as public safety, polycentric governance, and risk governance. Based on the detailed research in the field of management, the current situation of urban public safety combined, the establishment of public safety governance analysis framework, combined with the existing public safety governance problems, analysis, and research of public safety governance strategies, and the ways to improve urban public safety based on risk management (such as effective governance), the urban public safety governance proposed to propose improvement strategies, based on research results for exploration and improvement [4]. It is of positive theoretical significance because it can effectively combine theory and practice and further improve the theoretical system related to urban public safety governance.

Based on the background of emergency response to public safety events, this project researches and implements a robotic command-and-control system for public safety. On the one hand, it uses the advantages of robots' spatial accessibility, real-time controllability, and cooperation to improve the control of the emergency command-and-control system on the situation at the incident site, and uses the command-and-control system to solve the problems of slow response, weak command, control, and information occlusion in the response of individual robots. On the other hand, the use of advanced networks to achieve remote command and control, and the use of network technology, WebGIS, real-time data transmission, remote communications, artificial intelligence, and other real-time presentation of the scene situation, through the auxiliary decision support-related methods to assist commanders to quickly respond to events, improve the overall situation of each node robot to the scene of the grasp, decision-making, collaboration between each other, and the efficiency of implementation. Although actively exploring the integration and sharing of public safety video, innovative access methods, and following the relevant access specification requirements, the development of networking and integration of work programs, guidance around the integration of social video resource networking, the current public safety video surveillance is still in the public security organs to build, manage, and use as the dominant state, in the use of things that still have considerable space for mining. How to optimize the management mode of public security video surveillance resources based on the existing video network and video sharing service platform solves the problem of sharing and common use of public security video surveillance among departments. Our study is more efficient, more accurate, and more cost-effective than other studies. It has become a major issue nowadays to maximize the benefits of public security video surveillance resources, enhance the effectiveness of three-dimensional comprehensive prevention and control, improve public services and urban management, and enhance the ability of public security information to benefit the public.

2. Related Works

The city is a dense and complex special structural system. With the continuous progress of the economy, technology, and culture, the modern city is mainly driven by industrialization and informationization and gathers a huge number of elements to form an open and complex giant system. The close dependence, gradual differentiation, evolutionary change, and no-linear interaction among the elements in them are transformed into different distributions of time, space, and function through rise and fall. The city gathers many people and serves as the basic carrier of their productive life [5]. At the same time, human activity constitutes and governs the operation and development of cities. The individual units active in the city are constantly moving and changing, and present the normality and evolution of the city in a relatively stable group organization behavior. As an important component of smart city construction, it is crucial to cultivate a safe urban life form and create a smart and safe city [6]. The risk management model is constantly improved and optimized with the help of big data thinking and technology, and the systems and equipment related to comprehensive public safety emergency response, monitoring and surveillance, prevention and early warning, rescue, and command are constantly innovated, and the research of core hardware and software and the exploration of overall solutions are gradually launched [7].

In terms of subjects, some scholars believe that shaping the role of government guidance, community autonomy, and individual participation is a necessary path to optimize community public safety governance; in terms of platform construction, some scholars believe that the emergency management system is an important carrier for handling and transmitting various types of information in public emergencies and aiding emergency management decisions and that vigorously promoting the construction of emergency management information technology is an important means to effectively deal with urban emergencies [8]. It is an important means to effectively deal with urban emergencies, promote the effectiveness of government emergency plans, and enhance the emergency management capacity of urban communities [9]. In terms of mechanism, some scholars emphasize the need to insist on shifting the focus of public safety supervision downward and moving the gate forward, and to establish a sound organizational network for public safety supervision at the grassroots level; at the same time, it is necessary to absorb social forces utilizing social governance, mobilize multiple subjects, and integrate resources from all sides to realize the socialized operation of public safety supervision [10]. From the perspective of holistic governance theory, the establishment of a unified and integrated leadership institution for community public safety governance is the essence of cross-border cooperation, the partnership of institutions in different fields is the basic tool for cross-border cooperation, and the information network platform is the technical support for cross-border integration [11]. From the perspective of governance and collaborative government, some scholars also believe that a shift from loose cooperation based on government monopoly to an institutionalized collaborative model under government leadership should be realized among multiple subjects [12].

The rapid development and large-scale application of information technology have led to the gradual evolution of command-and-control systems with computers as the core, but the application of information technology in the system lags far behind the development of information technology itself. On the one hand, the system often shows a lag in intelligent assistance, failing to effectively combine various multimedia technologies, high situational awareness technologies, and intelligent auxiliary decision-making technologies. On the other hand, the relevant research focuses on face-to-face command and control, and not fully applies the development of reconnaissance and positioning technology, communication technology and network technology, and the implementation of remote command and control of the scene rescue personnel and their equipment, "man-machine" integration, and "full-area real-time dynamic" efficient command. With the development of intelligent robotics, a variety of special intelligent robots began to be developed and applied, such as rescue operation robots, reconnaissance robots, and fire robots, to provide strong support for the handling of public safety events. However, robots often perform tasks as independent individuals in incident response, mostly showing problems such as scattered emergency forces, slow response, weak command and control, and low efficiency in collecting and sharing information on-site.

3. Intelligent Monitoring and Early Warning Analysis of Public Safety Machines for Smart City Construction

3.1. Intelligent Monitoring System Design for Public Safety Machines in Smart City Construction. Public safety is a very complex system, and realistically, compared to national security, urban security, and social security, public safety is most closely related to people's daily lives. In other words, anyone who lives in a city has a great relationship with the public safety of the city [13]. From the previous research results on the connotation of public safety for other scholars, it can be found that the current research on the connotation of public safety is mainly focused on three aspects: one is the research on behaviors that endanger public safety at the legal level, the second is the research on professional public safety work, and the third is the research on public safety technology from the scientific perspective. By combining the research results of other scholars and the current direction of public safety research, public safety can be defined. Public security is the security of society and citizens, and from the perspective of public administration, it means that the external environment, basic values, interests, and institutions in the public sphere can maintain a fixed direction of progress and, as expected by everyone, ensure that the normal production life of society and citizens is not accordingly threatened.

From an economic point of view, a city is a network of economic factors and markets that intersect within a certain spatial area; from a geographical point of view, it is a dense agglomeration of people and houses in a suitable location; from a sociological point of view, a city is a form of social organization in which secondary and tertiary sector workers are the main population. The city is a complex of political, economic, and cultural elements that form a special area in which the inhabitants especially live, i.e., relatively free from agricultural production activities. It is clear from this that the key to urban security lies in the construction of a relatively stable system that brings together the various urban elements. However, the complexity of the various elements of the city itself makes it vulnerable to various factors in the process of managing the safe operation of the city, which in turn leads to the emergence of public safety problems [14]. As a basic element of the national structural system, the security of the city is related to the security of the whole country, so the upper layer of urban security is national security, and it is very important to manage urban public security well. This can be summarized that urban public security also means security from the perspective of the city; in particular, it also means that the city needs to follow certain laws and patterns in the process of development to ensure the stability of its operation, as shown in Figure 1.

Diagnostic analysis, discovery, and early warning of urban public safety events require spatiotemporal data of different modalities as data support, which is a gradual process of query conditions from rough to precise, so cross-modal retrieval of multimodal spatiotemporal data needs to be realized based on different needs at different stages. The multimodal spatiotemporal data retrieval for public security monitoring requires not only fast retrieval speed but also comprehensive consideration of cross-modal retrieval based on time, space, and semantics [15]. Based on the semantic-based multimodal spatiotemporal data association model and the spatiotemporal semantic integration indexing method proposed in the previous study, the spatiotemporal

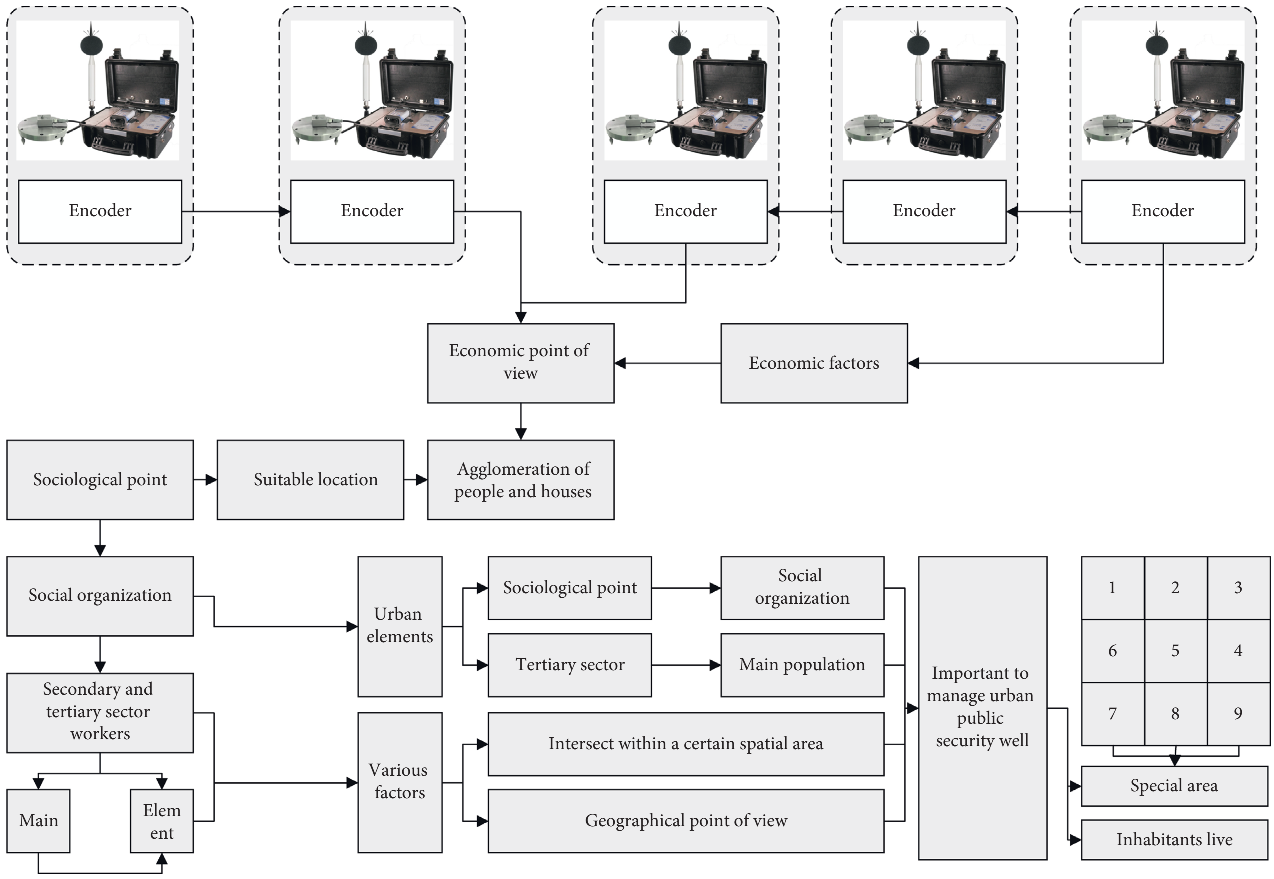

Figure 1: Intelligent monitoring framework of public safety machines for smart city construction.

association retrieval model will be studied from two aspects of spatiotemporal change objects and spatiotemporal change processes, and the cross-modal retrieval method for spatiotemporal change objects and the cross-modal retrieval method for spatiotemporal change processes will be proposed for the cross-modal retrieval needs of multimodal spatiotemporal data.

After the incident information is updated, the relevant plan is activated according to the basic characteristics such as the type and level of the incident. The relevant emergency members of the plan and the robot emergency team will arrive at the emergency site and immediately start a series of emergency rescue work following the contents specified in the plan. Referring to the laws and regulations related to emergency plans, the emergency plan of the robotic accusation system should form a system to formulate special emergency plans and on-site emergency disposal plans for all levels and types of accidents and all sources of danger that may occur, and clarify the responsibilities of relevant departments and relevant personnel in each process beforehand.

During the incident, and after the incident, in the preplanning management, in addition to the overall and special preplans for an incident emergency, the relevant preplans for robot emergency should be effectively supplemented so that the corresponding robot preplans can be activated according to the actual situation after the incident occurs to make a quick response. The robot command-and-control system's preplanning library mainly includes three major categories, as shown in Table 1.

To get rid of the problem that most of the cases can only see but not use the plan, the robot accusation system adopts intelligent process management of the plan, completes the process decomposition, analyzes each key node, and controls the progress of each key node [15]. The system provides a template for the preparation of the plan, and the user can enter the specific content and control the process of each key node in the plan, such as information reception, information transmission, and incident response. When an emergency occurs, the robot accuses the system of initiating and monitoring the process of the plan. First, according to the keywords of event type, level, and scope, the most similar plan in the plan database is automatically or manually matched, and the content of the plan is amended according to the actual situation. Then, each process task is issued according to the content of the plan, and the emergency resources involved are reasonably allocated. Finally, the task execution and resource dispatching are monitored in real time.

It is important to accurately locate the dynamic risk evolution in the city, advance the risk identification milestone and design, build a real-time chain-triggered strain mechanism for the local subsystems of the city, identify urban disaster risks as early as possible, and stimulate the

Table 1: Classification of preprogrammed.

Plan system	Illustration	Value
Comprehensive emergency plan	In general, it elaborates on the emergency guidelines, policies, emergency organization structure, and related emergency responsibilities for handling accidents	5
Special emergency plan	The basic requirements and procedures for emergency actions, measures, and guarantees are comprehensive documents for dealing with various accidents	8
On-site disposal plan	Target-specific accident categories	2

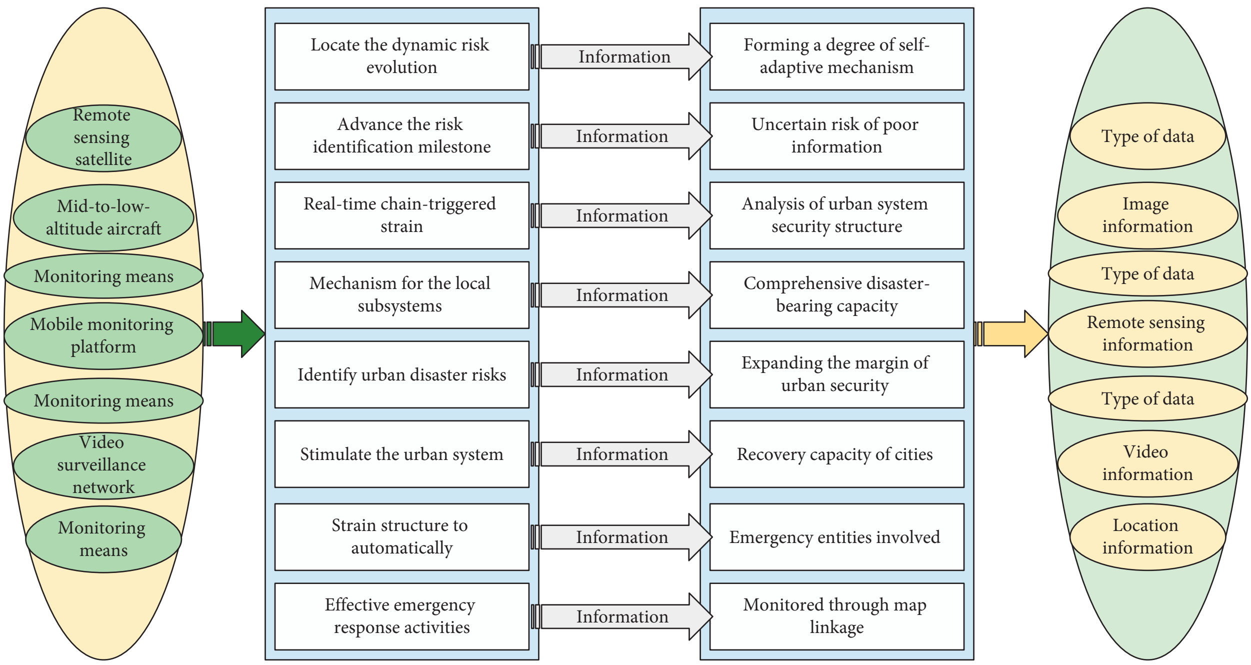

Figure 2: Public safety stereoscopic monitoring data acquisition and main data types.

urban system strain structure to automatically adjust to intervene in effective emergency response activities, thus forming a degree of self-adaptive mechanism for the uncertain risk of poor information. In addition, through the analysis of urban system security structure, it is easy to see that expanding the margin of urban security and improving the comprehensive disaster-bearing capacity and post-disaster recovery capacity of cities are important ways to ensure urban security, as shown in Figure 2. In the action phase, specific tasks are given to the robots and other emergency entities involved according to the specific content of the disposal plan, and the execution of the tasks is monitored through map linkage. In the above model, the arrows indicate the information flow, which runs through the whole process of the command-and-control system. The information involved in the robotic command-and-control system is generated and derived from the external environment and has the general characteristics of ordinary information, i.e., timeliness, transferability, dependency, sharing, falsifiability, and utility, so that the whole process of information acquisition, transmission, processing, and utilization is subject to higher requirements.

From the perspective of information flow in the command-and-control system, the data flow of the command-and-control system is analyzed [16]. The information sources of the command-and-control system mainly include two parts: the disaster site and the related emergency platform. As the main execution entity of the accusation system, the information of the robot includes the information of the body and the environmental information collected at the disaster site. The robot body information includes robot status, power, and other parameter information, while the disaster site information may include on-site video, pictures, and other sensor information. After the information is collected, the event emergency scene is presented to the commanders after the analysis and processing of the original data. After the commanders have sufficient knowledge of the event scene posture, they assist in developing the event disposal plan with the help of decision support-related methods. Finally, the commanders issue emergency rescue tasks to the executing entities on-site according to the disposal plan and monitor and adjust the emergency rescue process of the executing entities through real-time information feedback.

Different from traditional spatial data, public safety monitoring data not only have the massive and unstructured characteristics of traditional spatial data but also have multimodal characteristics. The multimodal characteristic refers to the data description of the same spatiotemporal object with multiple different forms and the characteristics of low-level feature heterogeneity and high-level semantic correlation between different modal data. For example, if the police want to use public security monitoring data to arrest a suspect, the police may identify the location of the suspect through the description of several different modal data such as video data and trajectory data of transportation. The multimodal nature of public safety monitoring data provides the possibility to support deep cross-modal analysis, mining, and application of multisource spatiotemporal data.

3.2. Design of Intelligent Monitoring and Warning Methods for Public Safety Machines. The key to making the huge amount of public data useful is data application, and the prerequisite for data application is data openness. Because of the limited technical power of the public sector itself, Hangzhou has introduced private organizations to provide technical services for the "City Brain" project [17]. According to the basic logic of "City Brain," it is easy to see that the private sector plays a leading role in the whole chain from data collection to data application. Taking traffic congestion as an example, the private sector has access to real-time video data from road video surveillance and can use the road traffic data it obtains to analyze and build models through algorithms to promptly adjust signals on-ramps and other roads to alleviate prolonged congestion; it can even use big data technology to make predictions based on real-time road conditions and plan routes for special vehicles such as ambulances. Private organizations can submit data requirements to the relevant departments according to their needs and perform operations such as cleaning, mining, and application of the data acquired after approval and consent. According to the complete chain of big data application, it is not difficult to find that while realizing the value of data, there is a possibility of data security problems occurring in each link of data collection, data cleaning, and data mining.

$$\begin{gathered}\Gamma_{ij} = \sum_{k=1}^{m} w_k^2 \gamma_{\mathrm{ijk}},\\ \sum_{i=1}^{p} \Gamma_{i\alpha} \leq \sum_{i=1}^{p} \Gamma_{i\beta}.\end{gathered} \tag{1}$$

Cities are complex systems, and the construction of smart cities involves different fields, and to share resources and information data, the platform to be built needs to be cross-agency and cross-departmental, which is a complex and systematic project. In this process, the fields with great strategic significance, strong driving force, urgent realistic needs, and wide and large benefits are selected to build relevant projects and works, to achieve results in the short term and form a systematic model; in this way, we can achieve results in a short period and form a systematic model, summarize experience and practice, gradually expand the application area, and lay the foundation for subsequent construction. The development of various construction and management specifications, including basic network standards, information service standards, and security standards, can guarantee the stable, safe, continuous, and efficient operation of the smart city system. The information infrastructure should be optimized and improved, technical standard specifications, application standard specifications, and operation and maintenance standard specifications including perception equipment and cloud foundation should be established to guide and regulate the smart city, and the engineering projects should be incorporated into the assessment system for regular review and evaluation against them to ensure that the project construction effectively promoted, as shown in Figure 3.

The top-level design of a smart city takes a holistic view, integrates all levels and elements of the system, involves multiple participants, and defines unified goals. It follows the principles of integrated planning, collaborative integration, resource integration and sharing, and services for the benefit of the people, and is people oriented and city specific [18]. Its construction program needs to have a wide range of universality; integration of academic, administrative, investment, and other authorities' demands; a combination of guiding programs and unified data formats and interfaces; and attention to the design of the city management system and operational development environment in addition to the technical aspects. The construction of smart cities requires timely, accurate, and comprehensive access to all kinds of data and information from the operation of the city, and in this process, intelligent infrastructure is the main source of providing information, and the establishment of a perceptible infrastructure layer is the underlying foundation in the technical architecture of smart cities. The data of each business area are usually distributed in independent subsystems, and the amount of data is very huge. The data extracted from the database have inconsistent formats and are incomplete data, which may not meet the requirements of the destination library, and when there is a software upgrade, the database architecture and the form of storage behind it are different, which are bound to bring about the upgrade, conversion, and processing of data, and the conversion of data is now. The conversion of data nowadays is inefficient, and in the application of IoT, there is also the problem of integration of old and new system interfaces and cross-system interfaces that cannot be accessed, resulting in the problem of data conversion and transmission. Therefore, the establishment of a unified data interface can realize high-speed data conversion and effective transmission.

$$\begin{gathered}w_i = \frac{\sum_{i=1}^{p} \Gamma_{ij}^2}{\sum_{i=1}^{p} \cdot \sum_{i=1}^{p} \Gamma_{ij}^2},\\ R(j) = \sum_{i=1}^{p} w_j^2 \Gamma_{ij}^2.\end{gathered} \tag{2}$$

The rule of law is to manage according to laws, regulations, and systems, using the rule of law thinking and the rule of law to solve the persistent problems of urban governance; intelligence is the future of urban refinement management; the key is to fully use modern technology and information technology, relying on the system platform to achieve information sharing, rapid linkage, and intelligent management; and standardization is to improve the

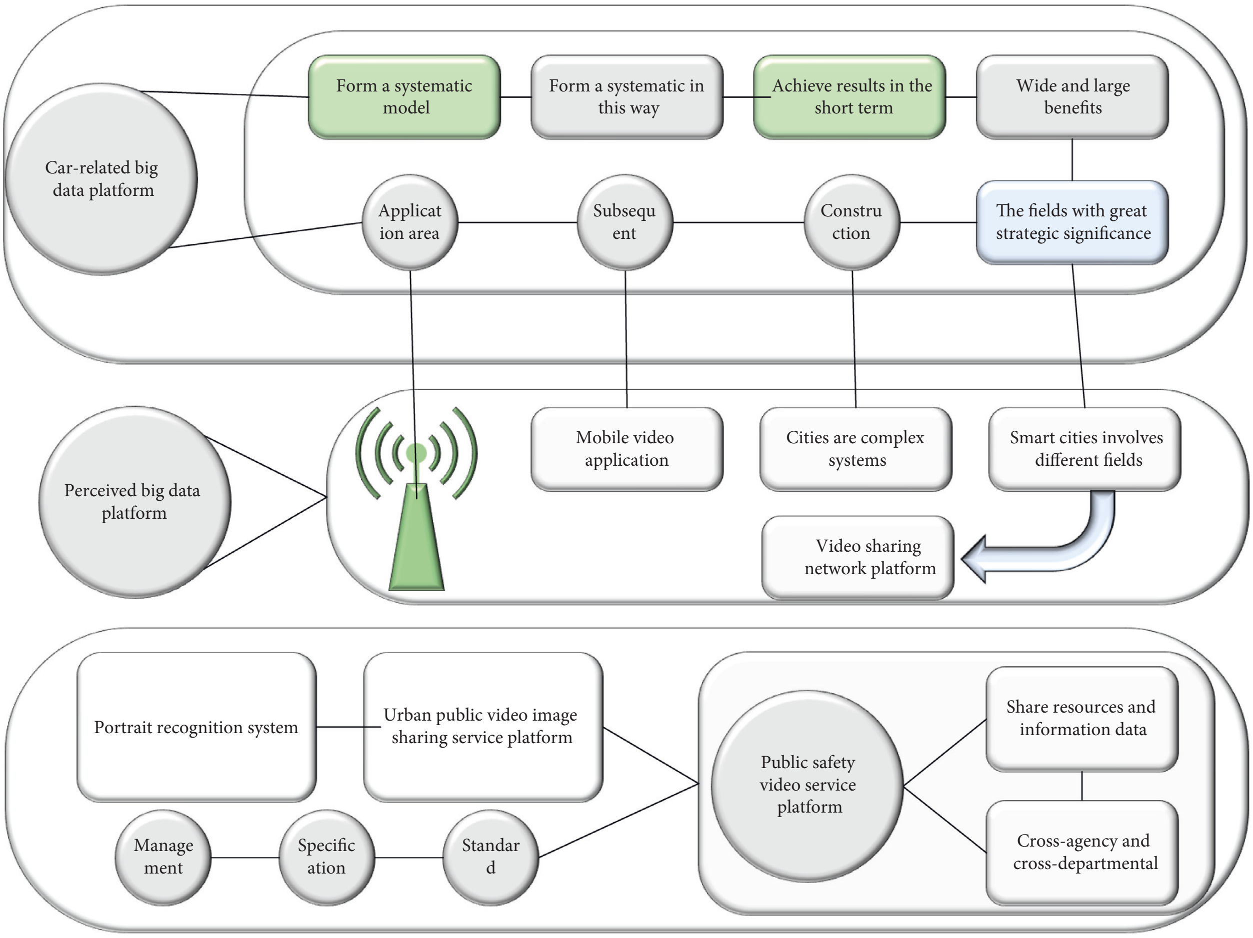

Figure 3: Public security video surveillance application system.

standard system for urban refinement. Standardization is to provide the basis for urban refinement management through a sound and complete standard system, integrating and unifying, bridging, and supplementing the scattered management standards of various departments, making them quantifiable, assessable, and traceable; socialization is to realize the diversification of management subjects, relying only on government departments for management that is not enough; and only by integrating the power of social, market, and other diversified subjects can we achieve the level of refinement management, requiring the social diversified subjects to do their duty while the government management responsibilities are in place [19]. Refinement in the field of urban management is to apply the concept of refinement in the process of urban management, to put people first, to seize the breakthroughs, to continuously promote the shortcomings, to promote the safety, order, and comfort of the city based on precise and scientific regulations and standards, to supplement with efficient and intelligent information technology tools, to adhere to the synergistic pattern of multigovernance, and to meet the interests of all social classes with better quality services and more humane management, as shown in Figure 4.

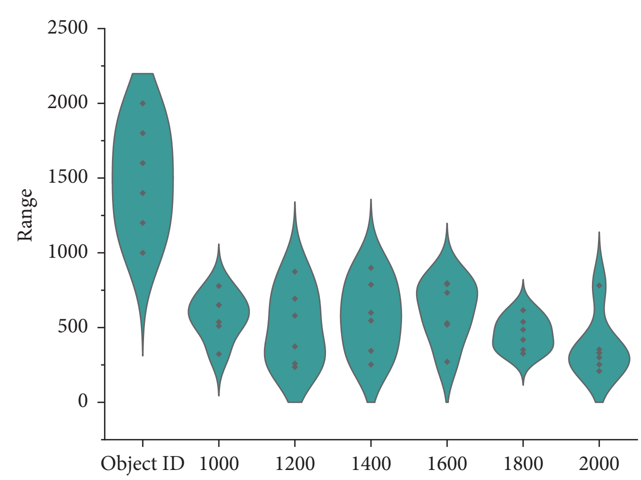

Figure 4: Monitoring early warning calculations.

In the case of data opened to the private sector by the public sector, not all public data can be opened to the private sector without conditions or boundaries. If public data involve the privacy of citizens, internal government secrets, secrets of commercial organizations, etc., and are opened to the private sector without conditions, there is a risk of improper use of the data by the private sector for profit.

$$z^{(1)}(t) = \left(z^{2}(2) + \frac{b}{a}\right)e^{-\alpha t} - \frac{b}{a}. \tag{3}$$

Public data should be classified into visible and useable data, visible and unavailable data, and unavailable and invisible data according to its level, importance, and confidentiality, and the data provided by the public sector to private organizations should be further subdivided on this basis. This will pose a great challenge to the security and authority of the government, and will also lead to security problems such as misuse of personal private data and theft of confidential business information by private organizations [20]. The government management center should be responsible for the senior leadership of government departments, and the team should be composed of full-time video information technology service personnel, supplemented by business departments and professional companies' research and development personnel, and clarify the responsibilities and tasks of the government management center and various industry departments, and following the division of responsibilities and the actual work needs of each department, video resource application authority should be reasonably allocated, and each division of the duty, working closely together to grasp the video surveillance construction, management, application, maintenance, and other aspects of the work, becomes the primary link to ensure that the video application is to deepen and enhance the use of benefits.

4. Analysis of Results

4.1. Intelligent Monitoring System Performance Results. It is also a highly practical and operational issue. From a practical point of view, different regions have different management requirements, and it is equally necessary to conduct in-depth research on this aspect in the process of public security governance and seek more effective management models. However, from the overall situation, there are still shortcomings in the overall public safety governance research, which leads to governance work greatly affected. In the process of urban public safety governance, it is necessary to pursue the alignment of interests, and the law is the basis for ensuring the alignment of interests and achieving efficient management. In the process of urban public safety governance, legalization is the key to ensuring the stable operation of the government administrative system and the autonomous system and is an important basis for coordinating the interests of the government and the interests of society. From the current situation of public safety governance, there is not yet a perfect system of laws and regulations for disaster mitigation and relief, which leads to the problem of unclear responsibilities in the process of urban public safety governance, especially when it comes to how to do the reconstruction and rehabilitation work within the shortest practice after the occurrence of a public safety incident, which is a lacking area at present.

The first is the most fundamental need for survival, which is reflected in access to food and drinking water. In the preparation of emergency shelters, in addition to the preparation of these substantive materials, it is necessary to calculate the amount of material distribution and the number of days of supply through the statistics of the number of evacuees and emergency materials in the place, so that the managers can improvise and deploy in time to guarantee the needs of evacuees; the second is the living needs, namely, rest and accommodation, washing, and excretion. In this process, it is necessary to monitor in real time the status of various pipeline networks, stability, and safety of the built accommodation facilities. In conventional emergency shelters, it is necessary to send stationed or testing personnel, but in the construction of smart cities, such workforce can be saved, as shown in Figure 5.

Access to information data and command platforms is required. These include the collection of the situation of people on-site and the monitoring of the status within the premises; a management platform that can display information and assist in decision-making; and the proficiency in changes in the surrounding environment to make predictions about the disaster situation and assist in decision-making about the next action instructions. The second is the demand for service output: through broadcasting and communication equipment, the command of the actions of the groups in the place; giving feedback and emotional reassurance to the affected groups; and the collection of the needs of the affected groups in the place. From the analysis of the top-level design of the smart city, promoting the construction of the smart city in various fields is not limited to the stacking of smart hardware in this field; similarly, the establishment of the emergency shelter cannot just be limited to the intelligent facility configuration of the place itself but should rely on the whole intelligent emergency system, from the four levels of the technical architecture layer by layer. Otherwise, it is an isolated set of intelligent hardware, without connecting it through a high-speed transmission network, without relying on the platform of cloud computing and big data processing and calculation, without forming the whole data sharing, without using the output of artificial intelligence and other technologies, etc. In this way, it also fails to grasp the essence of a smart city, and the manager cannot perceive the state of everything in the place in real time and cannot instantly obtain the needed data and information. It is not possible to capture the needs of citizens and make emergency responses in the first place, as shown in Figure 6.

When introducing larger-scale element information data, it will be possible to obtain more comprehensive element causality results, thus providing complete decision support for urban areas and overall fire emergency response capability improvement. When many similar cases of fire accidents introduced, the basis for risk diagnosis is enriched, and more references are available for judging the evolution of risk signs mapped by the state of each element in the grid cell, which will greatly specify the degree to which different elements affect the risk in different grid cells. Thus, the model can be used to create differentiated and dynamic capacity requirements and evaluation models for the grid cells at the end of the city and for the intermediate levels, thus providing a set of management technology solutions for urban fire safety adaptive mechanisms. The key to the

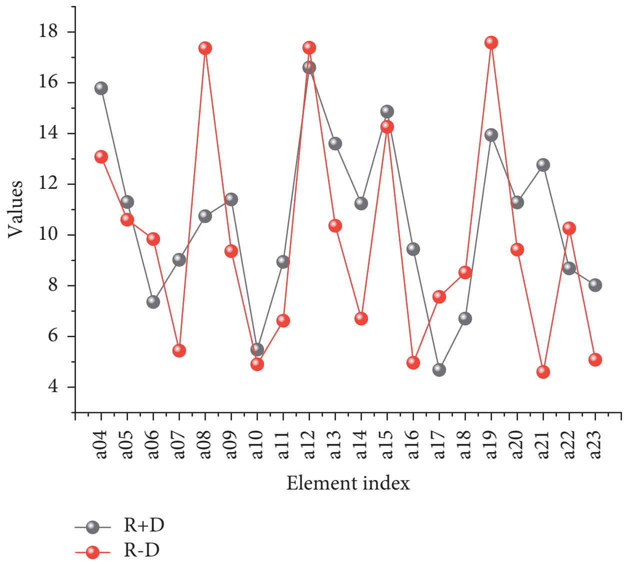

Figure 5: Centrality and causality of risk elements of grid cells.

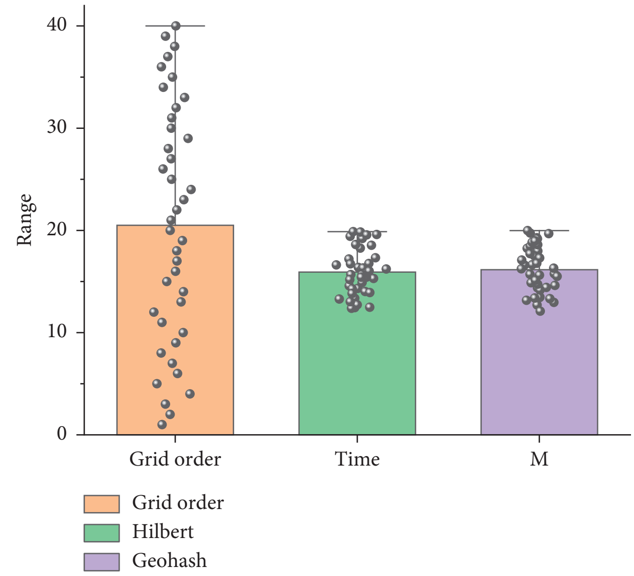

Figure 6: Operational efficiency.

sublimation of the comprehensive analysis from objective and correct to accurate and timely, in addition to the further optimization of the abovementioned model principles, lies in the maturity and improvement of the smart city platform, intelligence system, and the sharing mechanism of multifaceted information and data resources. Therefore, based on the actual operation of the experiments throughout this round of empirical calculations, fully combined with the current situation of urban risk governance, and oriented to the new era of urban regional fire safety risk diagnosis practice and adaptive mechanism construction tasks, the theoretical research of related initiatives is further carried out in the following from three aspects.

4.2. Intelligent Monitoring of Early Warning Results. As far as the regulatory platform itself is concerned, the lack of uniformity in the regulatory platform makes it possible for differences and disagreements to exist in the monitoring results of the same data, which adversely affects the timely implementation of government decision-making and emergency disposal, as the relevant personnel needs to verify the authenticity of different monitoring results before they can make decisions on whether and how to carry out emergency disposal, which misses the best timing. The lack of regulatory monitoring of the definition, algorithm, testing, and release of public data will make the use of public data by private organizations out of the control of the public sector, and private organizations may perform certain illegal and unlawful operations on the data in pursuit of commercial value, resulting in unpredictable, uncontrollable, or even irreversible consequences. With the advent of the cloud era, cloud technology has provided great convenience for data storage, etc. However, after the business goes to the cloud, the public sector's control over its data and business systems is weakened, and some of the management and operation, and maintenance rights are controlled by cloud service providers, and there is a lack of effective regulatory mechanisms and supervision means for cloud service providers, which may tamper, use, backup, or even sell public data on the cloud-based on their interests, resulting in serious public data security problems, leading to some public sectors' data on the cloud have doubts, as shown in Figure 7. Controls on network access are also not very strict. The inability to fully guarantee basic security means that data held within the public sector is at risk of external intrusion, and the leakage of certain confidential and sensitive data will have an extremely negative impact on the stability of society. In terms of monitoring technology, an immature and incomplete monitoring system may not be able to promptly detect hidden data risks, resulting in emergency response work not being carried out in the first instance and the damage caused by data security problems not being kept to a minimum.

As far as emergency disposal technology is concerned, without advanced disposal technology, even if the monitoring system issues a data security alert for the first time, it cannot make a rapid response, or even if the emergency disposal system makes rapid disposal at the first time, it cannot respond to and thoroughly solve the emergency data security problem due to its low technical content, which will likewise produce security problems such as leaking personal privacy, commercial secrets and state secrets, and so on. The use of big data technology to achieve analysis and prediction is related to the amount of data, algorithms, and objectives. To achieve data prediction, it is necessary to have sufficient data volume, mature algorithms, and clear objectives.

The retrieval time overhead increases with the increase in data volume, but the overall retrieval time overhead of this study's index is lower than that of the combinatorial index, which is mainly because this study's index merges the retrieval results of multiple behavioral processes, while the combinatorial index also requires the retrieval results of

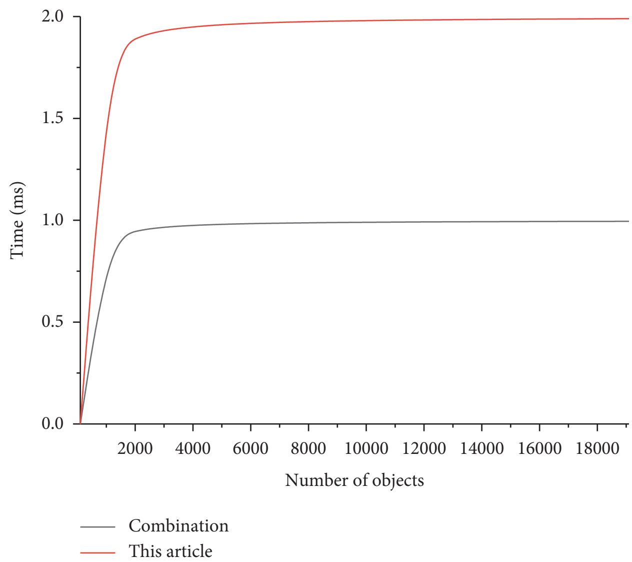

Figure 7: Comparison of early warning performance.

temporal, spatial, and semantic associations in each behavioral process retrieval separately before this merging. In addition, as the data volume increases, the retrieval time of this index grows slower and the gap between the retrieval time of this index and that of the combinatorial index gradually increases, mainly because as the data volume increases, the retrieval time is not only affected by the number of retrieval results merged but also by the semantic saturation, with the increase in data volume, the semantic information contained in the data content tends to be saturated, i.e., the amount of keywords tends to be stable, and the time of the word dictionary matching stage tends to be stable. The above experimental results indicate that the retrieval performance of this study's index for the event change process is better than that of the combinatorial index, and the larger the data volume, the higher the retrieval performance of this study's index.

5. Conclusions

In this study, we propose a semantic-based multimodal spatiotemporal data association model for the characteristics of low-level feature heterogeneity and high-level semantic correlation of multimodal spatiotemporal data. Based on the feature-semantic mapping mechanism of spatiotemporal data, the model uses ontology theory to construct a semantic expression model of multimodal spatiotemporal data and realize the normalized semantic expression of multimodal spatiotemporal data; on this basis, the temporal correlation, spatial correlation, and semantic correlation calculation methods of multimodal spatiotemporal data are proposed to realize the correlation construction and correlation metric of multimodal spatiotemporal data, which provides model support for public safety monitoring-oriented data. It is found that smart cities have not paid enough attention to the field of urban public safety, and there are no in-depth development and application in smart emergency response. The robot application module is combined with related technologies to develop and implement four aspects of robot data communication, situational display, auxiliary decision-making, and command and dispatch. Public data security management is a continuous project, and due to the differences in the interests of the subjects, the supervision mechanism should be carried out throughout the process, while technical means, policies, and regulations need to be constantly improved to cope with new problems that constantly arise. In the future, we will conduct more in-depth research on this basis and apply it in practice.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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Research Article

Innovative Research on Collaborative Design of Blended English Teaching in Higher Vocational Colleges Based on Digital Technology

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By combining the advantages of online teaching and offline teaching under digital technology, blended teaching can break the limitation of time and space, which reflects the transformation of the "student-centered" teaching paradigm. With the expansion of the blended teaching scale, how to analyze and match the features through the data of learners' learning behaviors to improve their learning efficiency and teachers' teaching level and quality has become an urgent problem. Therefore, in this paper, collaborative design is carried out for blended English teaching platform in higher vocational colleges, where students' cognitive ability and difficulty of teaching resources are cooperatively matched. At the same time, blended recommendation of teaching resources is implemented based on collaborative filtering algorithm, thus developing a matching algorithm in light of the above dynamic adjustment. The results of the iterative test show that the platform can optimize the current English teaching mode and enhance the learning feedback between teachers and students, thus improving students' English learning level.

1. Introduction

At present, Internet not only plays an optimization and integration role in the allocation of production factors, but also is introduced into the basic requirements of public English teaching in colleges. It emphasizes the significance of actively introducing computer and network technology that can enhance students' consciousness and enthusiasm in English learning. Under the background of the new situation, with the rapid development of network information technology in China, various English autonomous learning platforms came into being [1–3]. Compared with traditional English learning methods, the network-based learning model can meet the diverse needs of students' learning resources, which helps students to manage their learning time flexibly. Moreover, it gives full play to the guiding role of network learning for students, which quickly improves students' English learning efficiency and effect. Under the above platform, students can be engaged in online English learning by combining the hot issues and contents that they are interested in and accumulate experience in English learning. However, in the face of massive learning resources, there is a serious problem of overload information, especially in the field of basic English teaching. The selective difficulty caused by information overload makes it difficult for learners to quickly find the learning content suitable for their own abilities, which not only delays their valuable time and reduces their learning efficiency, but also causes resistance to English learning [4, 5].

Combining blended teaching mode with digital technology can meet all kinds of needs of English teaching development. This teaching method of combining theoretical knowledge with practice can improve the traditional way of students' class learning and provide guarantee for the all-round development of their ability. In addition, the blended teaching mode provides rich resources for students, which can comprehensively improve students' comprehensive comprehension of English knowledge [6, 7]. At present, the application of the blended teaching mode is superficial, teachers have failed to strengthen the reform of traditional classroom teaching methods and create a learning environment based on the network platform. Therefore, it is significant to research the collaborative design of blended English teaching in higher vocational colleges under digital technology, which can integrate the public English teaching mode and methods with modern teaching forms, so as to promote the effective development of English teaching.

2. Establishment of Blended English Teaching Platform

2.1. Connotation of Blended Teaching

2.1.1. Significance of Blended Teaching. The implementation of blended teaching involves students, teachers, colleges, and other subjects. In fact, it has formed a complex system, which also brings challenges to blended teaching [8]. However, digital technology gives a good solution. Various Internet tools such as Internet system management platform and Internet information storage provide technical support for blended teaching system management that mainly includes teaching evaluation system, teaching resource sharing system, teaching curriculum arrangement system, etc. Through the blended teaching mode, teachers can not only teach through the network but also make preparation for class, assign homework, correct homework, and answer questions online. Similarly, students can interact with teachers online to solve the confusion about English learning [9, 10].

2.1.2. Digital Support for Blended Teaching. The development of digital technology provides a reliable mobile platform for blended teaching. Students' extracurricular practice cannot be separated from the support of abundant network resources, so the interactive design of learning content, including content structure design, multimedia presentation design, problem design of teaching content, and operability design of teaching tasks cannot be separated from the support of mobile platform [11, 12]. The use of the mobile platform can greatly expand the space of class, and teachers can communicate with students through various ways, such as network teaching platform before and after class, so as to keep abreast of students' learning situation and their feedback. Especially, the establishment of college resource sharing platforms has created a harmonious, open, interactive, and exploratory environment for students, which enables students to freely discuss problems with online students or teachers equally and easily through the network, and always maintain a positive self-activation state in the learning process.

2.1.3. Existing Problems. Due to the characteristics of learners and learning resources, the traditional network teaching platform cannot effectively adapt to the blended teaching mode, and it is difficult to integrate the learners' changing cognitive ability and the difficulty of learning resources for personalized collaboration. In addition, most online English teaching resources are simply piled up, which is not only a lack of semantic and logical hierarchy of knowledge points but also a lack of marking of knowledge points.

2.2. Recommendation of English Teaching Content

2.2.1. Recommendation Based on Teaching Resources. Recommendation based on teaching resources is to use the content attributes of teaching resources to predict the information related to it and users' personal information. The system recommends learning resources for learners that are similar to their past studies, hobbies, and abilities [13]. This method can not only avoid the cold start problem of learning resources but also analyze the relationship between learning resources first and then implement the recommendation [14]. It finds the relevance of resources in terms of content according to the annotation metadata and then recommends similar learning resources to users based on user's historical learning records, as shown in Figure 1:

We model the metadata of learning resources, then discover the similarity between learning resources through these metadata, and finally, make recommendations according to the similarity. Content-based recommendation only considers the nature of objects and forms a set of objects according to tags. If the learning resources that users like appear in this set, other objects in the collection are recommended to them [15, 16]. In addition, it needs to use related technologies to describe learning resources and learners' personal information, as well as strategies and algorithms that can compare personal information with content description. Its architecture diagram is shown in Figure 2:

The recommendation system only uses the current user's preferences and related historical learning records to build the personal information model, which presents the reasons why content resources are recommended by the way of display (content features or descriptions). In addition, it can also recommend new content without any comments from users, which can make good use of learners' interests and receptivity to model, thus making the recommendation result more accurate [17, 18].

2.2.2. Recommendation Based on Learner's Ability. Accurate mastery of students' English knowledge and learning ability is helpful to better implement the "online" part of blended teaching. The recommendation based on learners' ability is based on learners' personal characteristics (existing knowledge base, cognitive characteristics, learning style, etc.) and demographic information (age, gender, place of residence, interest, etc.). First, the algorithm takes learners' personal data to automatically cluster and group students and then recommends different learning contents according to specific learners' abilities. Learners can choose their own learning materials, learning methods, and evaluation methods that best suit their own characteristics. The basic process of the recommended algorithm is as follows:

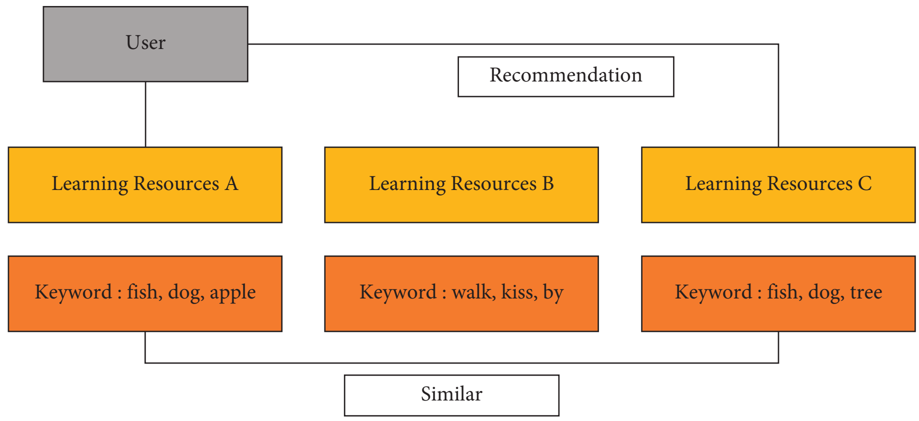

FIGURE 1: Recommendation of English teaching content.

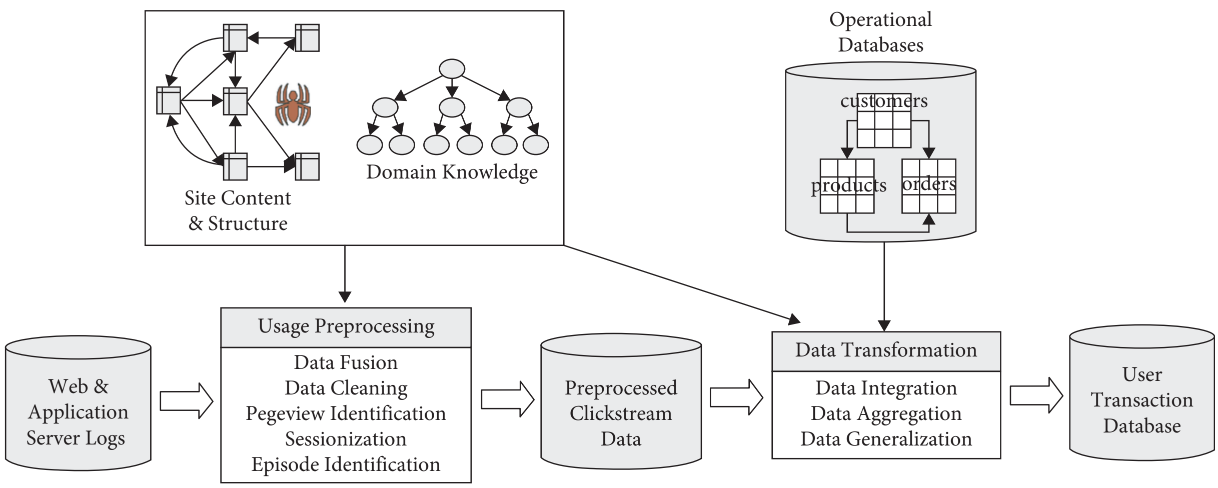

FIGURE 2: Framework of recommendation on English teaching content.

(1) Obtain information of learner's ability

(2) Look up the matching information of ability and difficulty

(3) Search for learning resources by using the information of difficulty matching

(4) Check the recommended result set, and if the result set is larger than the preset list length, go to step (6); if it is less than the preset list length, continue to (7); otherwise, return to (5);

(5) Output and display the recommendation list

(6) Reduce the difficulty standard to retrieve learning resources again and back to (4)

(7) Increase the difficulty standard, re-search the learning resources, and back to (4)

2.2.3. Recommendation Based on Collaborative Filtering. Both user-based recommendation and teacher-based recommendation need to obtain relevant information. User-based recommendation needs to obtain user's rating data and their "interests and abilities," while teaching-based recommendation needs to obtain teacher's curriculum design [19]. Collaborative filtering recommendation can overcome the problem of recommendation based on users, teachers, and English teaching resources. When the description information of teaching resources is incomplete or difficult to obtain, collaborative filtering algorithm can make recommendations through feedback from other users.

The biggest feature of the collaborative filtering recommendation algorithm is that it considers the similarity between users and makes full use of collective wisdom; that is, it digs out a small number of user groups (clustering grouping, which is called neighbors in collaborative filtering) that are similar to their interests and abilities among users. Afterward, an ordered list is formed according to the collection of objects related to them for recommendation [20, 21].

2.2.4. Blended Recommendation. Due to the personalized differences of users' learning, it is not only users' ability and resources that can be used as the basis for recommendation but also can be based on their learning records, hobbies, and learning results. In addition, collaborative filtering recommendations can be made according to users with the same ability level and learning resources. Because of the difficulty of learning resources and the error of cognitive ability calculation, an algorithm may only be suitable for parts of learning resources or learners. It is necessary to establish a configuration framework of individual-based learning resources or individual learner recommendation algorithm. In addition, the framework of the recommendation algorithm is generally based on a configurable mechanism. Therefore, the usage scenarios, targeted users, data on which recommendation depends, recommended data sources, and applicable scope of the recommendation algorithm are analyzed. Moreover, combined with the configuration parameters of data, a configuration framework of blended recommendation algorithm is designed, which designs all kinds of recommendations into system processes that can be called independently and specifies the storage locations of input data and output results, thus realizing the separation of the recommendation algorithm from the system platform and achieving the goal of dynamically configuring or adjusting the recommendation algorithm. Under the framework, the general flow of this recommendation algorithm is as follows:

(1) Learner user login
(2) Open the page that contains the function of recommendation
(3) Income navigation information for the page and user parameters
(4) Search the recommendation algorithm configuration table of users and page positions
(5) Obtain the type, dependent data, and the output position of the result the in recommendation algorithm
(6) Obtain recommended dependence data
(7) Call the recommendation algorithm process to transfer recommendation dependent data and user information
(8) Recommend the algorithm to be executed, record the output result to the established position, and notify the caller to complete it
(9) Check the recommended calculation automatically
(10) Obtain a recommendation result list according to the calculation result mark

The whole process involves learner, pages, background algorithm scheduler, the process of recommendation algorithm, and detection program, whose collaborative design process of teaching resources is shown in Figure 3.

Algorithm 1 shows the recommendation algorithm.

2.3. Microservice Architecture. Because the online English learning platform is a multiuser system based on the Internet, the microservice architecture is adopted in this system architecture model [22]. Microservice architecture is an architecture style, which organizes a series of collaborative services into a system to support business. The aim is to decouple the whole scheme by splitting the functions into discrete and independent services where each microservice can be independently developed, deployed, run, and upgraded. Compared to the traditional Java Web development method, the microservice architecture can be implemented by means of containers or virtual machines [23].

In order to follow the development principle of “low coupling, high cohesion” and realize the robustness and scalability of the code, layered technology is adopted for the establishment of this platform. Different layers are responsible for different functions, and the layers are combined through API interface calls, as shown in Figure 4.

In order to better reduce the coupling between layers, the software implementation is generally divided into three-tier architecture, and object-oriented programming is adopted. The upper layer calls the lower layer through interfaces, while the lower layer provides services to the upper layer, which is the implementation class of the lower layer interface. The API interface of the service standard is the same, and the service provider can change it. The three-tier architecture consists of a user interface layer, business logic layer, and data access layer, each of which has the following functions:

(1) User interface layer, which is responsible for interacting with users
(2) Business logic (BL) layer, which is mainly aimed at the operation of specific problems, can also be represented as the operation of data layer and the logical processing of data business
(3) Data access layer, which mainly operates on the database, not data, and specifically provides data services for the business logic layer or user interface layer

3. Testing of the Platform

3.1. Test Method. During the test, the recorded data of users’ learning process are used, and more than 100000 user information, 40000 English sentences, 30000 words pronunciation data, and 500 English article data in the system are selected. The test process used user tables, user learning tables, teaching resource tables, and so on. In order to better realize blended teaching, the learner’s test and feedback are recorded. The matching index of resources is defined as the ratio of learning score and cognitive ability of resources; that is, after the user finishes learning, the learning content is tested by the test bar, and the obtained score is divided by the user’s cognitive ability and multiplied by 100%, as shown in formula (1). If the recommended learning materials meet the user’s cognitive ability, users will be asked to complete the relevant test questions after learning the resources, so as to check whether they have mastered the knowledge and ability contained in the resources. If the user fails to complete the learning or test questions, it means that the recommendation does not meet their cognitive ability. Otherwise, it means that the resource is in line with the user’s cognitive ability.

$$\text{MatchRate}\,(\%) = \frac{\text{TestSore}}{\text{CogAT}} \times 100\%. \tag{1}$$

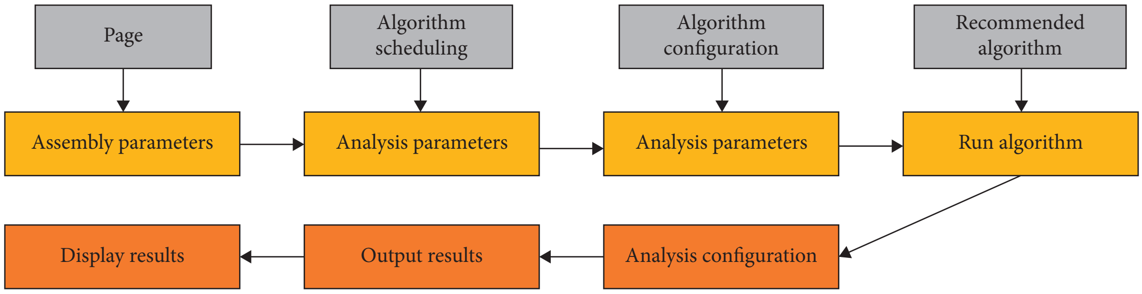

FIGURE 3: Collaborative design process of teaching resources.

```
Public float repeat value (Document doc1, Document doc2) {
  Float keyword TFIDF = 0.0f;
  Float doc1 TFIDF = 0.0f;
  Float doc2 TFIDF = 0.0f;
  For (String word: doc1.getContentTerms().keySet()) {
    If (doc2.getContentTerms().containsKey (word)) {
      Keyword TFIDF += doc1.getContentTerms().get(word);
    }
    Doc1 TFIDF += doc1.getContentTerms().get(word);
  }
  For (String word: doc2.getContentTerms().keySet()) {
    Doc2 TFIDF += doc2.getContentTerms().get(word);
  }
  Return (keyword TFIDF/doc1 TFIDF) * (keyword TFIDF/doc2 TFIDF);
}.
```

ALGORITHM 1: Recommendation algorithm.

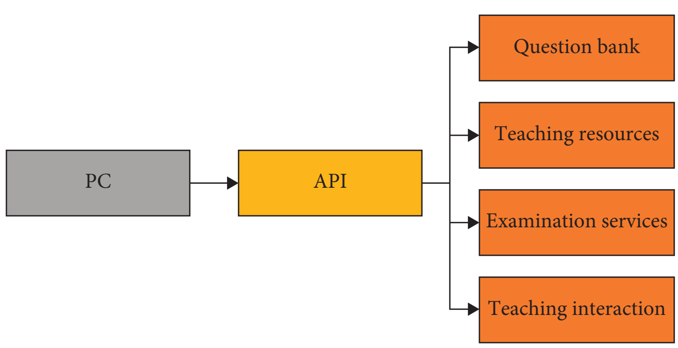

FIGURE 4: Architecture of blended teaching platform.

In the formula above, MatchRate indicates the degree of matching between learning resources and users' abilities, TestScore indicates the test scores of users after learning resources, and CogAT indicates users' cognitive abilities.

The evaluation system consists of process evaluation (mainly online evaluation) and summative evaluation (mainly offline evaluation). Online learning is mainly scored by online quantitative indicators, while offline learning is mainly scored by offline nonquantitative indicators. The blended teaching mode is mainly synthesized from the three processes before class, during class, and after class and the final evaluation. In each process, students can get online quantitative index scores and nonquantitative index scores evaluated by teachers.

TABLE 1: Test results of blended English teaching platform.

Grouping parameters	Iterations	Cluster average diameter	Calculation time (seconds)
3	80	4.6	1265
8	40	6.2	1038
12	20	6.9	1728
29	10	7.4	1189

3.2. Test Results. Firstly, the cognitive abilities of learners' users are calculated and grouped according to their cognitive abilities. The main basis of grouping is the geometric length of students' cognitive attribute vectors that mainly includes

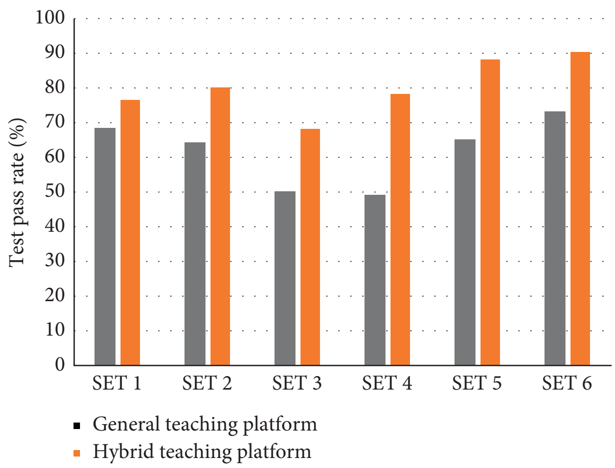

Figure 5: Comparison of students' test pass rate.

the cognitive abilities of age, vocabulary, and learning duration. The test results of grouping number and execution efficiency of related algorithms are shown in Table 1.

According to the results in the table above, when 8 groups are selected in groups and 40 iterations are selected, the execution efficiency is relatively high. In addition, the test results of college learners divided into 8 groups are in good agreement with the actual subjective judgment. The guiding significance of the test data lies in that we are basically in accordance with the actual test results. When students are grouped according to different learning stages, the cognitive abilities of students in each group are similar. If the grouping span is too large, the difference of cognitive abilities within the group will be larger, and the matching degree may decrease according to the recommendation of clustering grouping.

The matching effect of teaching resources is compared. For six groups of data, the number of users who have successfully passed the test on the blended English teaching platform is compared with the number of users who have passed the test on the original platform (the matching coefficient is over 60), and the result is shown in Figure 5.

It can be seen from the figure that under the original teaching platform, the lowest pass rate of users from SET1 to SET6 is below 50%. After adopting the blended recommendation algorithm, the collaborative feedback between users and teachers is obviously improved, and the test pass rate of students under the blended teaching platform remains above 65%, which is significantly higher than that of ordinary teaching platform. It shows that the promotion effect of the blended teaching platform on students' English learning is targeted and meets the learning ability of users. For teachers, the appropriate evaluation mechanism enables the platform to be used as an effective auxiliary tool for English teaching in higher vocational colleges, so as to truly advance learning and teaching through evaluation.

4. Conclusion

The blended English teaching mode based on digital technology can integrate modern technology with traditional teaching, and greatly improve the teaching quality of English in higher vocational colleges. By analyzing the shortcomings of blended English teaching at present, this paper designs a blended network teaching platform for higher vocational English, including the recommendation of teaching resources, overall structure, collaborative codes, etc. Moreover, the platform matches students' cognitive ability with the difficulty of teaching resources and tests the platform through the users' learning records and test completion. The results show that the collaborative feedback between users and teachers is significantly improved after the blended recommendation algorithm is adopted, and the test pass rate of students is above 65%, which is apparently higher than that of ordinary teaching platforms.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Innovative Research on College English Teaching Mode Based on Strategy Reasoning Mechanism

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In the era of artificial intelligence, the traditional English teaching methods cannot meet the increasing demand of course learning at this stage. Therefore, in this paper, a brand-new English teaching model based on strategic reasoning mechanism is designed by analyzing the problems faced by construction of network curriculum in universities. By introducing the idea of artificial intelligence, the student model and teacher model are designed, and the separation of teaching content and teaching strategy is realized. The development of the system adopts B/S structure and relies on lightweight J2EE multitier framework. At the same time, the overall architecture, functions, and processes of the teaching system are analyzed and designed. The system is convenient to transplant and expand, which has certain practical value and can provide reference for the design of various teaching systems and the innovation of teaching modes.

1. Introduction

With the continuous penetration of information technology into the field of education, artificial intelligence has played an important role and has been paid attention to and recognized by more and more educators [1, 2]. Artificial intelligence, as a rapidly developing technology, has brought new advantages to the reform of college English teaching and provided a possible path for the construction of efficient and high-quality college English teaching. The interaction and infiltration between artificial intelligence technology and college English teaching has promoted the diversified development of teaching methods and modes, thus playing an active role [3]. Reform of college English teaching from the perspective of artificial intelligence is reflected not only in the improvement of teaching quality, but also in the improvement of students' interest in English learning. It is conducive to upgrading college English teaching from static passive learning to dynamic active learning, thus leading to the overall optimization of college English teaching ecology [4]. Relying on artificial intelligence, the teaching of listening, speaking, reading, and writing can be more vivid and three-dimensional, thus creating a modern intelligent English teaching system which is not to promote the complication of college English teaching, but to use advanced technology to present English in the simplest and most popular way for students, creating new perspectives and possibilities for college English teaching.

With the rapid development of artificial intelligence and network technology, web-based foreign language teaching websites or software appears one after another. However, the current online English teaching systems are mainly based on students' self-study and teachers' off-line answers, where students cannot get corresponding guidance [5]. In addition, there are also numerous English databases, online dictionaries, and online translation websites on the Internet. These tools can only translate and explain specified words and phrases, but cannot analyze a certain sentence and actively give learning guidance. Therefore, it is of great significance to study a new English teaching model with intelligent analysis function and corresponding learning guidance for different students.

2. Related Theories

2.1. Object-Oriented Knowledge Representation. The core idea of object-oriented technology includes objects, classes, encapsulation, and inheritance. Classes, subclasses, and instances form a hierarchical structure, which supports the classification and representation of knowledge and enables knowledge to be organized in a certain form [6, 7]. Object-oriented knowledge representation is mainly based on abstract data types, which is convenient to represent the static characteristics, real-time state, and interobject association of complex objects.

Because each object has three important parts: inherent attribute, operation behavior, and relationship with other objects, four base classes are established according to the object-oriented idea: attribute class, behavior class, entity class, and relationship class. The conceptual model of object-oriented knowledge representation is shown in Figure 1.

The attribute class is used to represent all the basic attributes of objects, the behavior class is used to represent all the basic behaviors, the relationship class is used to represent all possible relationships between entities, and the entity class is used to represent all objects. Commonly used knowledge representation methods [8] are the following:

(1) Predicate logic representation:

The main knowledge in artificial intelligence is often expressed by first-order predicate logic. Predicate logic representation can express things that cannot be expressed by propositional logic, but it still has some shortcomings for the representation of complex problems.

(2) Production rule representation:

Production rule is a widely used knowledge representation in expert system at present. The knowledge of causality is generally expressed by production. Its basic form isas follows:

IF P THEN Q

in which P is the precondition of the production formula; Q refers to the conclusion or operation obtained when condition P is satisfied. The meaning of the production formula is expressed as follows: if the premise P is satisfied, the conclusion Q can be deduced or the operation specified by Q can be performed.

2.2. Strategy Reasoning Mechanism

2.2.1. Data-Driven Forward Chain Reasoning Algorithm. According to the existing information of the problem, the context is established by adopting the rule forward. If the condition of the rule can be correlated with the existing facts, the rule is considered to be available. If there are several rules that satisfy the conditions, the conflict resolution strategy is used to select one, and add the fact of the rule to the context [9]; then repeat this process until the problem is solved or reasoning fails. The algorithm is described as follows:

Procedure Forward Beasoning (rulers)

{while (context fact ≠ target fact) Do

Call the procedure Select_rulers to generate available rule sets;

While (R ≠ NULL) Do

{Call the procedure Conflict _ Resolution (R) to resolve conflicts and generate executable rules; Call Operration _ block to add the conclusion of the rule to the dynamic context; }

}

2.2.2. Goal-Driven Backward Chain Reasoning Algorithm. By assuming factual goal and searching the knowledge base, the rule set that may match the fact can be found out, and then check the condition part of each rule in the rule set. If a rule can be correlated with the current data provided by the user, add the conclusion part of the rule to the database. Otherwise, take the condition item of the rule as a target, recursively executing the described process until all the subtargets appear in the context or the subtargets are not further solved [10]. For the latter, backtracking recurs again. The algorithm is described as follows:

Procedure Backward Reasoning

Set the initial reasoning goal and set the initial fact DB; Generating an optional rule set R by using the initial target matching rule;

While (R ≠ NULL) Do

{Take one in order as an executable rule; Record the condition position of dynamic database and target library; Call the procedure for recursive + backtracking antecedent matching;

IF (each sub-goal in the target library appears in the dynamic DB) THEN

Add to rule base;

}

IF (natural number) output reasoning failed;

Exit.

2.2.3. Framework Reasoning. First, find a description suitable for all current problems, and then use context reasoning of the framework to find the undiscovered facts, and make relevant operations among the factors (Figure 2).

Specific framework reasoning can be divided into static and dynamic. For static framework, static knowledge is used to represent framework, which corresponds to Rule and static fact in production system [11]. Dynamic framework is a dynamic information set generated in the process of framework reasoning, corresponding to Rule_based. This paper adopts the static reasoning framework, and its implementation code is as follows:

Procedure Frame Handler

Set initial information and dynamic framework set; Set the reasoning end flag to False;

While (reasoning end flag = False) Do

Taking out the activated static framework;

{Whi1e (current framework ≠ NULL) Do

{IF (query reasoning = True)

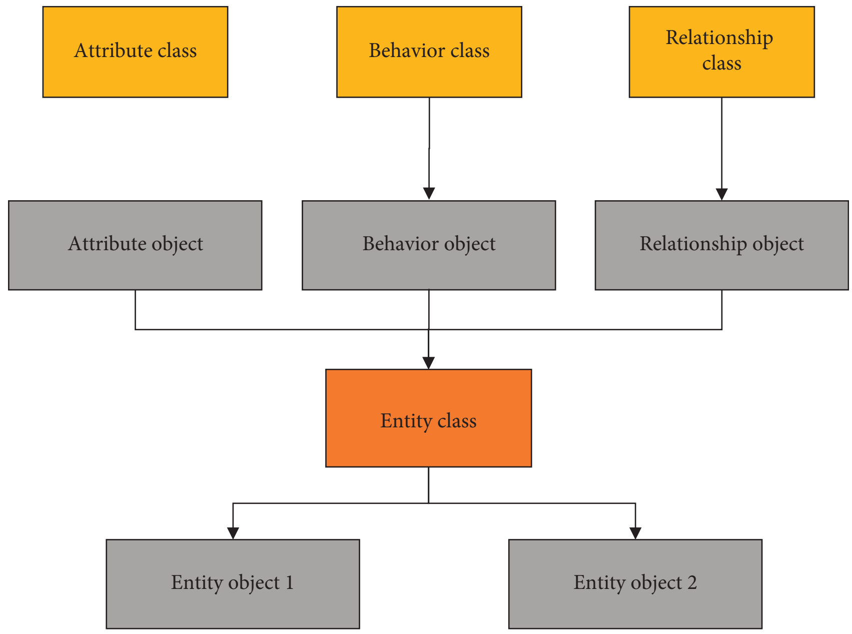

Figure 1: Conceptual model of object-oriented knowledge representation.

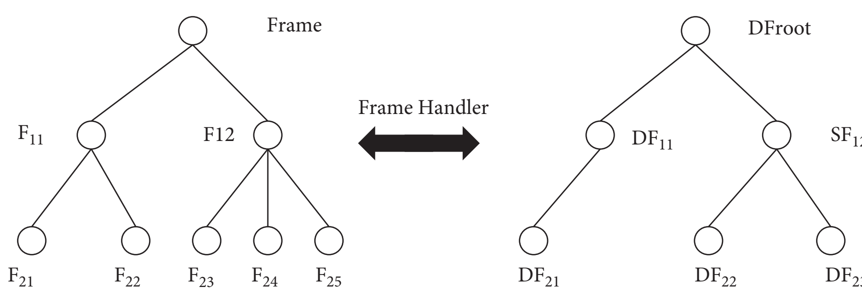

Figure 2: Process of framework reasoning.

{Take the case face value of corresponding factors; goto A}

IF (default reasoning = True)

{Take the side value of the framework factor; goto A}

IF (inheritance reasoning = True)

{Take the subframe, get the side value of the framework factor, and call recursively; goto A}

IF (procedural reasoning = True)

{Call the corresponding procedure and get the side value of the framework factor, goto A}

A: fill in the static framework (or dynamic) corresponding factors of the side value of the factor;

Reset the current static framework;

Set the reasoning end flag False or True (according to the reasoning situation);

}

}

2.3. J2EE Architecture. Java, often used as one of the back-end development languages of websites, has integrated many convenient frameworks. The system of education and learning platform is developed by J2EE with the object-oriented characteristics of Java [12, 13]. By combining MVC pattern and related frameworks, distributed architecture and cluster are used to improve the throughput of the system and make its architecture simpler and clearer. To make a dynamic website system, it is necessary to provide a server and database for web applications, so as to analyze and display front-end pages, handle business logic, and read related data.

J2EE architecture reduces the cost and complexity of developing multitier applications by providing a middle-layer integration framework. The middle layer can meet the requirements of high reliability, practicability, and scalability [14]. The unified development platform of J2EE can support the implementation of existing applications and can also fully support Enterprise Java Beans, which enhances the security mechanism and improves its performance [15]. The framework is shown in Figure 3.

2.4. Lightweight Framework. Lightweight framework is a programming pattern relative to heavyweight framework (typically EJB) [16]. This is because J2EE platform is a service provided by multiple suppliers, which comprehensively develops enterprise-level application products. On the one hand, the lightweight framework can be developed by simple

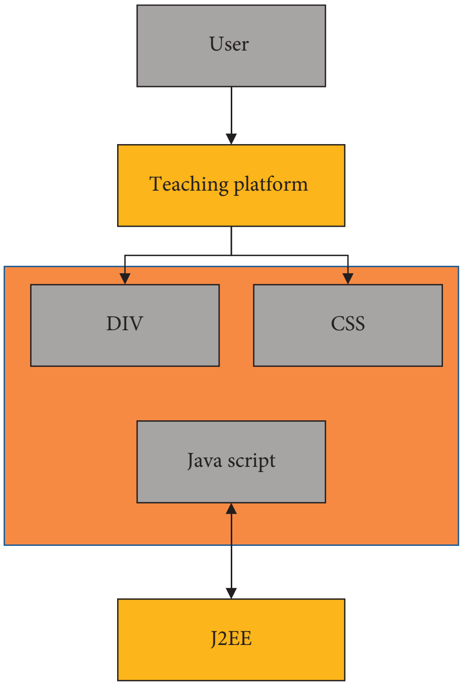

Figure 3: Interactive framework of J2EE.

Java Beans method, which can reduce the dependence of applications on containers and improve the development efficiency. On the other hand, most lightweight frameworks belong to open-source projects, and there are a large number of ready-made source codes, which help to reduce the difficulty of developing projects. In addition, lightweight framework has the following advantages [17, 18]:

(1) Adopt control inversion mode and aspect-oriented programming. It is not necessary to write a lot of code for executing developers, abnormal or managed connections, and it is easy to solve the dependency problem of objects. This not only separates the business logic from the basic framework, but also reduces the complexity and enhances the maintainability of the application.

(2) Lightweight framework provides management business. Due to its modular attribute, it is not required that business objects must follow the specific interface of the platform. Developers can develop based on POJOs to improve the efficiency.

3. Architecture Design of English Teaching System Based on Strategic Reasoning Mechanism

3.1. Overall Architecture. The systematic architecture is designed as B/S three-layer structure. B/S structure is easier to improve and expand than traditional C/S structure. The C/S structure requires that every terminal client must install the client program; otherwise it cannot work. This limitation makes poor compatibility and universality of the C/S structure [19].

The three-layer model of B/S structure includes the presentation layer (PL), the logic layer (LL), and the data layer (DL). The structural diagram is shown in Figure 4.

The presentation layer, also known as the interaction layer, is the interface between users and the whole system. It provides the user interface of application programs for displaying data and accepting data input by users. The client can run the software only by installing a WEB browser.

The business layer is a WEB server, which realizes the business functions of applications, and almost all business processing is managed in the middle layer. The middle layer is user-oriented, and the information input by the user interacts with the data layer through the middle layer, which mainly processes data business for specific problems [20, 21].

The data layer is a database server with student model and teacher model, while all kinds of data analysis, processing, and other operations ultimately come down to the access to the database in data layer.

Among them, the access between layers is strictly limited, and the logic layer can only access the data layer, while the presentation layer can only access the logic layer. Instead of directly accessing the database, users should connect to the middle layer and interact with the database through the presentation layer [22].

3.2. Functional Architecture. This system includes four kinds of users: experts, teachers, students, and administrators. When users log in, they have different module operation permissions according to different identities.

Expert: Expert refers to a senior English expert who has authoritative and profound knowledge in the field of English major and can thoroughly analyze the knowledge points, degree, and certainty involved in English test questions and give the system samples in the established format. The main permissions include knowledge base maintenance (adding, querying, modifying, and deleting static knowledge base and dynamic knowledge base), sample maintenance (adding, querying, modifying, and deleting), and password modification.

Administrator: they refer to the staffs who have the right to maintain the system daily. The authority mainly includes the management of system users, and the management of question bank includes adding, inquiring, modifying, and deleting.

Teachers: they are English teachers. One or several English teachers are assigned to each course according to the number of students' elective courses. Teachers' rights include viewing students' information, mastering students' learning progress, analyzing the knowledge of designated students or groups, organizing examinations, and analyzing test results.

Students: they refer to the registered students in this system. Their main rights include taking part in online learning in online classroom, self-study, examination, using intelligent analysis or diagnosis system to analyze the knowledge points they have learned, and obtaining relevant suggestions, intensive exercises, personal information modification, etc.

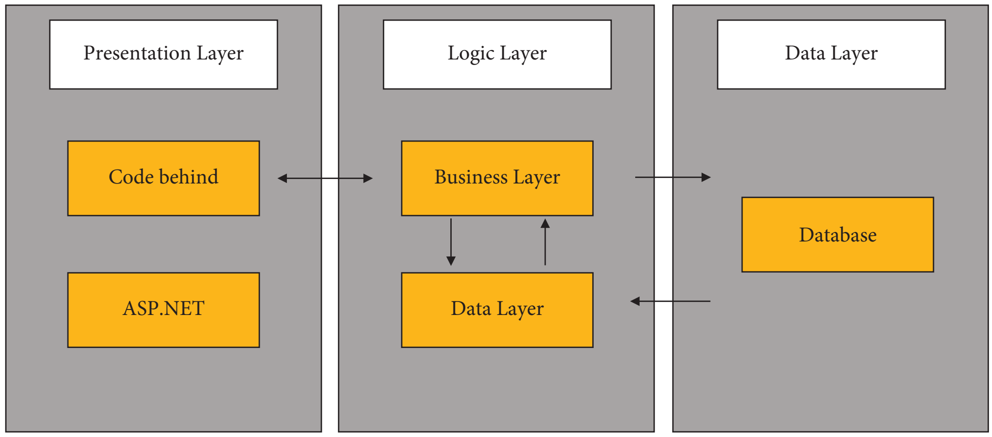

Figure 4: B/S architecture.

The system consists of three subsystems, namely, online teaching system, web-based teaching resource database, and teaching management system. The online teaching system is the main system, which mainly provides students with the functions of online real-time receiving and autonomous learning after class. The web-based teaching resource database is the supporting system of the main system, which contains all the resources of teaching and learning, such as courseware, video and audio material database, learning strategy database, corpus, and various teaching resource databases. Students can obtain materials from the resource pool to strengthen or expand their knowledge, while teachers can integrate the materials in the database for teaching or testing.

The online teaching management system is another supporting system, which mainly records, monitors, evaluates, and feeds back the teaching process, including registration module, grading test module, online learning record module, score analysis, and evaluation feedback module. The system manages the students' learning process when they have registered for courses online, analyzes the learners' learning progress, knowledge points, and grades, and establishes corresponding learning files for storage, so as to dynamically track and evaluate the students' learning activities.

4. Systematic English Teaching Mode Based on Strategic Reasoning Mechanism

4.1. Database Design. The data table of the systematic database can be roughly divided into the following types.

User information table: it contains 3 kinds of user information in the system, including user name, password, and user category.

Knowledge point table: it contains all knowledge points of English vocabulary and grammar, including category, name, difficulty level, number, knowledge point association level, and attribute.

Question bank table: its function is to save English test questions provided by experts, including questions, options, and answers.

Rule knowledge base table: it refers to the domain knowledge of experts in the form of rules, including object, object attribute, type, credibility, and fact description.

Strategy base table: the reasoning result descriptions of teaching strategy and learning strategy are saved in this table.

History information table: it is mainly used to save the history of visiting, learning, and practicing of various users.

Analysis table: it includes exercise analysis, knowledge point analysis, learning mastery analysis, and group analysis. It is used to determine feedback results in relevant situations.

4.2. Teaching Process. The traditional teaching mode is generally based on the teacher as the center to educate, while students passively accept knowledge. The Internet-based autonomous learning teaching mode is a new teaching mode with students as the center and teachers playing an auxiliary role. It strengthens students' ability to acquire, process, use, and memorize knowledge, which is of great significance for the learners to understand the research process, improve their quality, and cultivate the awareness of lifelong learning in the cognitive process. The teaching mode of a unit module is shown in Figure 5.

The process is based on the teaching unit as a cycle. For a certain teaching unit, firstly the teaching objectives and learning objectives of the unit are set, and the methods to achieve the objectives are provided. After entering the online class or autonomous learning system, the system provides rich learning resource and forms for students to choose, whether it is the learning of vocabulary and grammar in language knowledge or the learning of listening, speaking, and writing in language skills. It can be a video explanation or a small game of set scene. The next stage is the class training. In this stage, the teacher guides the students in reading, writing, and translation; then, students form a group for interactive training. The fourth stage is the practice, which mainly trains the students' communication skills and improves their relevant abilities by designing a series of activities combined with the social reality which include group discussion on current affairs at home and abroad and filling in the application form for studying

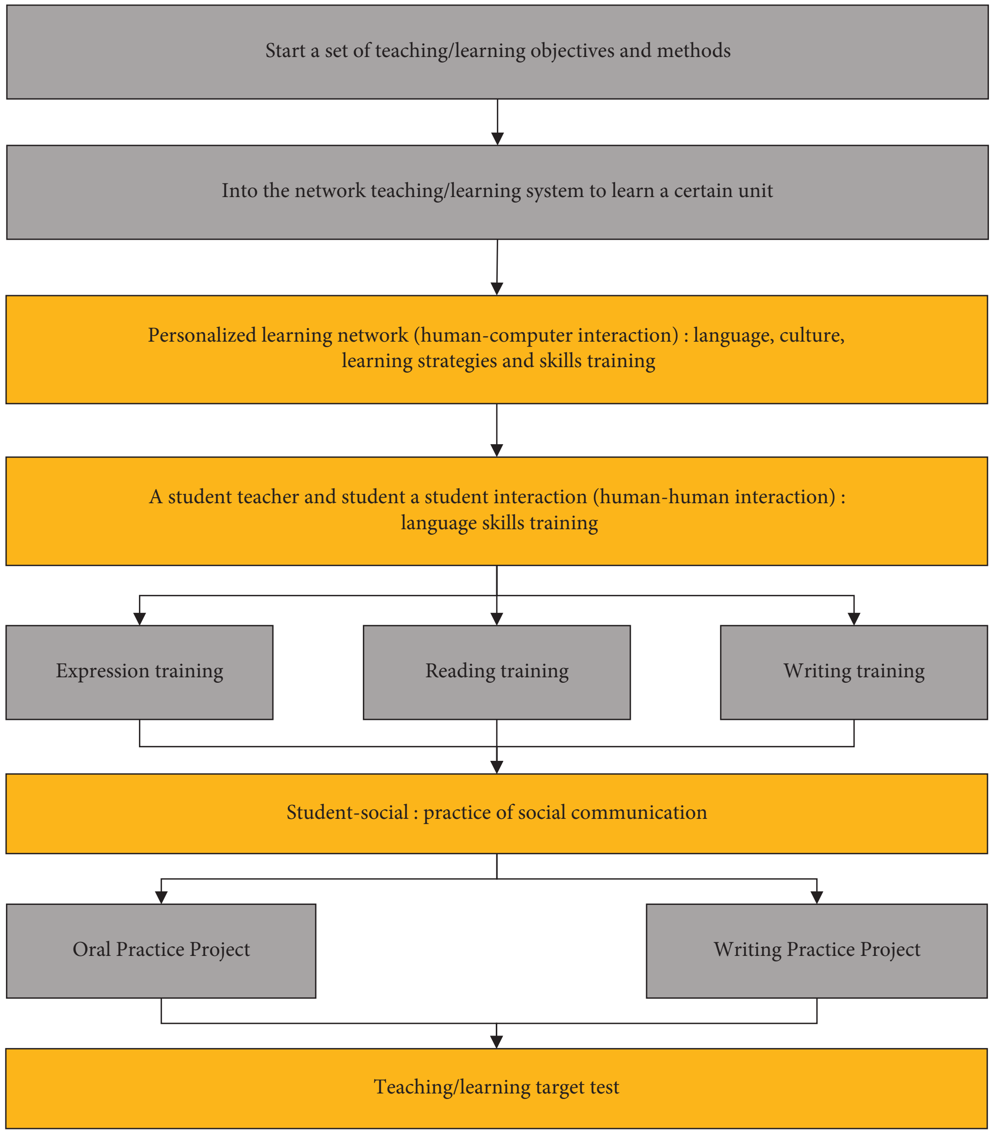

Figure 5: Structure of systematic English teaching mode.

abroad. After the completion of the above stages, users will enter the teaching/learning test. If the preset teaching objectives and learning objectives are reached, the cycle will end and users will enter the next cycle. Otherwise, the students will return to restudy according to the mastery of knowledge and skills which contains three kinds of situations: return to communication layer, return to language skill training layer, and return to language learning layer.

4.3. Construction of Knowledge Base. The key point of establishing intelligent teaching mode is the construction of knowledge base, which involves the division of knowledge points. In fact, the basic understanding and memory unit of knowledge concept constitutes the whole teaching content. When learners associate each knowledge unit, the overall structure of the concept can be formed, which is beneficial to understanding and reviewing.

In this teaching mode, the mastery degree of knowledge points is set as 1–6 to quantify the students' understanding of a certain knowledge point, which means that they have mastered, comprehended, understood, not understood, learned, and not learned. The first four are used to describe the degree of mastery of the knowledge point, and the last two are used to judge whether the knowledge point is included in the learning process. When a student first browses a knowledge point, the knowledge point is added to the student's knowledge point model and marked as learned. When they complete a test about the knowledge point, the system will carry out intelligent diagnosis according to the knowledge point and related knowledge points and analyze the students' proficiency level and the causes of errors, thus giving learning suggestions.

The framework of knowledge points judgment in this system is composed of four factors, namely, score, reading capacity, accuracy, and elapsed time. Factor 1, score, refers to the idea that after entering the system, the student first conducts some knowledge tests within the specified time to roughly understand the overall situation of the their mastery of relevant knowledge. The remaining three factors refer to the completion of the students' systematic learning of the knowledge of the unit and the completion of the exercises in the unit. This framework encodes the four factors that determine students' learning level, and the coding order is "S," "R," "C," and "T," while each factor may have multiple values. Infer factor belongs to inheritance reasoning and is a subframe, also known as the lower framework, which is a further logical reasoning of the objective described by the current framework. The lower framework is named according to the infer factor of the upper framework, which can be expressed by production rules.

Taking the judgment that students have mastered the knowledge as an example, the framework rules are as follows:

Rule

Frame name: state decision rule,

Factor 1: score ("very high, more than 90"),

Factor 2: reading capacity ("all, 100%"),

Factor 3: accuracy rate ("very high, above 95% "or" high, 70%–94%"),

Factor 4: elapsed time (less than or equal to "average shortest time"),

Infer factor: judge the learning level of the student as "mastered").

This framework corresponds to different combinations of the values of the four factors and can be simplified to a simple table structure without nesting:

Rule (1, "mastered," [S1, R1, C1/C2, T1]).

Here, "/" is used to indicate the relationship of "or" in the rule. Because the fact and rule of Prolog cannot express the relation of "or" in a clause at the same time, the accuracy rate of answering questions can be one of two cases to split into clauses.

The infer factor corresponds to another framework, which can further evaluate or suggest the student's learning level as "mastered," for example,

Rule

Frame name: learning level is "mastered"

Factor 1: value of level judgment ("excellent"),

Factor 2: value of cognitive ability ("high"),

Factor 3: value of teaching strategy ("enter the next unit").

4.4. Strategy Reasoning Mechanism. Reasoning is a process that starts from the known conditions and gives the corresponding results by querying the relevant rules in the strategy base. According to the characteristics and objectives of the system, the data-driven method is adopted as follows:

(1) Initialize the rule base and add the known facts into the rule base according to the format required by the system.

(2) According to the state of the current student model, the known facts (known conditions) are extracted and added to the comprehensive database.

(3) According to the known facts, the rules existing in the rule base are matched. If contained, execute step 4; otherwise execute step 7.

(4) Execute the selected rules and marked rules. If necessary, execute the rules; otherwise the conclusion will become new facts and be put into the database.

(5) Search the comprehensive database. If there is a solution to the problem in the database, it indicates that the problem is solved and the solving process is finished. Otherwise, return to step 3.

(6) If there are unused rules in the rule base, and they do not match the facts in the comprehensive database, it means that the problem has no solution and the process is terminated.

(7) If there are no unused rules in the rule base, it means that the problem has no solution and the process is terminated.

If the process of solution fails, it means that the system has not recorded this situation into the comprehensive database. The system should give teaching suggestions according to the student model and basic teaching principles. The basic teaching principle refers to something with obvious regularity in the teaching process [23]. Although it cannot reflect the teaching experience of individual teachers, it is still scientific and effective in accordance with the basic teaching rules. In the process of systematic reasoning, multiple rules may satisfy the conditions. In this case, the priority of rules should be set to resolve the conflict of rules.

5. Conclusion

Implementing research on the innovative teaching mode of college English class in the era of artificial intelligence can catalyze the reform of English teaching. Therefore, in this paper, a teaching mode of English teaching system based on the mechanism of strategic reasoning is proposed. By introducing the idea of artificial intelligence, the student model and the teacher model are designed to separate the teaching content from the teaching strategy. Through the design of system database and teaching process, aiming at the construction of knowledge base, a strategy reasoning mechanism suitable for English teaching is put forward where a lightweight framework is adopted to provide the combination of presentation layer, logic layer, and data layer, which improves the development efficiency. It is a convenient system for transplantation and expansion and has certain practical application value; at the same time, it can provide reference for the design of various teaching systems.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Innovative Research on Collaborative Design Mechanism of Cave Dwellings in Henan under Cloud Environment

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Collaborative design is an important link in building construction at present, while the communication and cooperation among disciplines need further regulation. In order to maintain the cost-effectiveness and design quality of building engineering in the competitive environment and obtain higher economic benefits, the design team must ensure the collaborative design quality of building engineering. Based on the analysis of collaboration theory and collaboration mechanism, a collaborative design platform for caves in Henan province is constructed under the current cloud environment. In addition, the requirements and non-functional requirements of the platform are analyzed, and the overall structure with each part is designed specifically, hoping to improve the quality of collaborative design effectively.

1. Introduction

For the building industry, the traditional design presents a linear pattern. After the independent design of each major is completed, the information *r* is relatively independent, which is not conducive to the integration of design data and information [1].The collaborative design mode under the building cloud platform can enable all majors to design collaboratively in a parallel way and solve the problem of noncommunication data through the building cloud platform [2]. Furthermore, different forms of architectural design can be displayed on the same platform, and all designs are completed in three-dimensional state, without space imagination of two-dimensional drawings [3].

Henan province is located in the transition zone between the second and third steps in China, and its topography is very complex, with many types of geographical features such as mountains, hills, basins, and plains. Under the influence of specific natural environment, residents living in mountainous areas, hills, tablelands, and gullies have created cave dwellings with local characteristics. Cave villages contain the ecological wisdom of residents' site selection and construction. However, compared with ordinary villages in plain areas, the economic development of Henan cave villages is generally backward, the economic industry of the villages can no longer meet the employment needs, and a large number of rural populations, especially the young and middle-aged people, are constantly flowing into cities. It directly leads to the aging and waste of cave villages. Therefore, it is necessary to carry out innovative research on collaborative design mechanism of Henan caves. In this paper, Henan cave dwellings are taken as the research object, and its design collaboration platform is built, hoping to realize the innovation of architectural design innovation mechanism.

2. Overview of Collaborative Design in Henan Cave Dwelling

2.1. Synergy Theory. German physicist Haken established the synergy theory and put forward that competition is the premise of synergy. The open system develops from stable state to unstable state, and the system spontaneously forms a new relatively stable state through internal synergy effect. In this process, with the change from disorder to order, from discrete to whole, it can generate new energy exceeding the total of each subsystem [4].

The understanding of "cooperation" can be divided into narrow sense and broad sense. The narrow sense only contains the meaning of cooperation. Broadly speaking, it includes the dual states of cooperation and competition, and the final result is a win-win situation. [5] The cooperation described in this paper is generalized cooperation. Participants in various industries and their behaviors form a social system, and participants are in a state of constant competition that can highlight the significance of cooperation. In the process of competition, participants absorb other people's knowledge for their own use, or provide their own knowledge to others in the process of cooperation, so that they can be integrated in the process of giving and receiving. New energy can be generated, which exerts greater efficacy and producing a cooperative effect of $1 + 1 > 2$. Therefore, collaborative behavior is a spontaneous and indispensable link in the development of industry and society, a catalyst to promote knowledge and technology innovation, and of great significance to advance science and society [6, 7].

2.2. Collaborative Design of Henan Cave Dwelling

2.2.1. Design Basis of Henan Cave Dwelling. The parapet wall is set on the kiln face in Henan cave dwelling, that is, the top of the kiln, and the flower wall is formed by brick carving, and the overlapping neckline is similar to the courtyard wall. The face of the kiln is also decorated in the form of the hanging flower gate building on the door wall, and embossed patterns are made on the kiln face and wall. The face decoration of the kiln is relatively complex, and the whole kiln is decorated with brick carving pattern of hanging flower curtain. Referring to the modeling characteristics of the garden's hanging flower gate building, bas-relief is generally made on the surrounding parts, with the top circle and the bottom square so as to conform to the cosmology of "unity of nature and human." In addition, there are "upper bright windows" on the door of the cave dwelling, and the window lattice will be carved with simple patterns. Niches will be set on the east and west sides of the cave door to worship relevant gods, and corresponding carvings will be made around the niches, as shown in Figure 1.

2.2.2. Design Characteristics of Henan Cave Dwelling. Building multi-agent synergy mechanism is divided into internal coordination and external coordination. The internal synergy mechanism is based on the interior of the multi-agent coordination system. According to its own characteristics, by establishing a reasonable organizational structure, information transmission mode and benefit distribution standard, and so on, it gives full play to the maximum advantages of each subject so as to achieve common goals and strive for the maximization of overall benefits. The external synergy mechanism is to promote the cooperation of all subjects in the system through external conditions, such as policy, market, and environment [10]. The establishment of the synergy mechanism is conducive to the cooperation of all participants in the competition. Through mutual learning, integration, and innovation, the core values of enterprises can be enhanced, and the risks brought by environmental changes can be resisted [11]. The scope of this paper is the multi-agent internal synergy mechanism, which can overcome the shortcomings in the process of building construction and show its advantages of development by jointly establishing the work flow and rules system.

Figure 1: Front eave wall of Henan cave dwelling.

The characteristic of Henan cave dwelling is that almost every component is decorated with carving and color, and the techniques used by different decoration carriers are also different. In the selection and use of patterns and patterns, according to the shape of decorative parts and material characteristics, the conformal processing and the application of art according to the material fully show the beauty and artistry of the material, as shown in Figure 2.

Although there are many types of decorative themes and patterns, there are also repeated patterns. The same kind of pattern is in different positions; the outline of the graph and the combination of the graph expression are not the same. From the point of view of the decorative parts of the pattern and the graphic expression of the pattern, the pattern will adopt the conformal processing techniques according to the morphological changes of the decorative parts so that the pattern is highly consistent with the body, which reflects a high degree of coordination both from the content and form expression.

3. Demand Analysis

3.1. Business Analysis. In order to carry out innovative design of Henan caves, A Design Institute is selected as the design company to carry out the construction of collaborative design platform.

A Design Institute employs nearly 200 people, including about 120 designers, more than 50 project managers, and project procurement and other management departments. The number of large and small projects carried out in a year exceeds 30, and the projects are generally managed by stages, such as establishment stage, feasibility study stage, project preliminary design stage, detailed design stage, construction management stage, and so on. The project is initiated by the management department, and the preliminary work of the project is carried out after being approved by the leaders of the company, including planning, engineering estimation, and other work, and the planned tasks are distributed to the

Figure 2: Characteristics of Henan cave dwellings.

design department to carry out the design. Then, the department of design will carry out the management according to the requirements, including the preparation, modification, audit, capital raising, and countersignature of the design documents, and finally submit the construction drawings for the project construction. In the process of construction, there will be design alteration and construction rework, and so on. After the final construction of the project is completed, the department of management prepares the completion data and organizes the acceptance of relevant parties of the project. If the acceptance fails, rectification is required, and the project will be delivered after the acceptance of the project is passed.

Co-design of cave dwellings project mainly includes general layout, architecture, structure, water supply and drainage, heating, ventilation, and electricity, and some unconfigured design majors usually choose outsourcing design. Professional design software includes AutoCAD, Revit, MicroStation, and other domestic CAD software. According to the requirements of the project owner, the project design includes both 2D drawing design and 3D model design. Like most architectural design company, *Z* Architectural Design Institute still focuses on 2D drawing design with supplement of 3D modeling. In order to cultivate the 3D modeling ability, a BIM team of 10 people was set up to carry out 3D forward design and explore the modeling mode of 3D model, the process of model verification, model demonstration and construction management, and so on.

The traditional project drawing proofreading is that after printing the drawings, the personnel are organized to hold a meeting for centralized audit, fill in the drawing audit sheet, feed back to the designer, and then print the drawings again for audit. After many times of printing and modification, the final version of the project construction drawings is finally formed until there is no review and modification opinion. The process of drawing proofreading is very time-consuming of paper and personnel [12]. When the design task is tight, the designers often work overtime to solve the project design schedule, and employees will complain about it. In addition, management includes project manager, construction management, project cost, safety administrator, and data management, and project resources, plans, and costs are managed through the existing project management system [13].

Generally, the project site is located in different places, and the information is communicated with the staff in the office of the design institute by telephone and e-mail, so it is difficult to record the process information through the project event document [14]. Design drawings are generally transmitted through instant chat software and network disk, and the confidentiality of project information is uncontrolled [15]. If the updated drawings are not transmitted in time or the notes are inaccurate, it is easy to cause information asymmetry, which makes the design and construction inconsistent and requires rework.

Without the management of document system, the project documents are scattered on the computers of project personnel. There is no unified standard for the line shape, line color, drawing frame, and font of project drawings, and the drawing naming is not strictly in accordance with the specification requirements. When the project is completed and delivered, the final archived drawings and forms of the project often have errors in version and content, part of the project management information is even missing, and some forms specified in ISO quality system are often filled in after the completion of the project, which has laid hidden dangers for the design quality management and also brought certain difficulties to the project settlement and subsequent maintenance and reconstruction of the project. The existing OA system has solved the audit and archiving of office documents, and the project management system solves the tracking management of project resources, plans, and costs but cannot meet the requirements of design management.

3.2. Overview of Platform Requirements. The co-design platform of cave dwellings needs to support the existing professional design software, can flexibly customize the catalogue structure of engineering projects, store and manage various documents and materials of projects, and support online proofreading and annotation of 2D design drawings and 3D models. The platform is deployed in the local area network of the company and can be published on the Internet for access by other participants of the project. The platform also needs to have API interface to realize data interaction with other systems.

3.2.1. Synchronize the Architecture. Reduce the repeated entry of project data, automatically import the project management architecture in the project management system into the design management platform, and automatically give information such as attributes so as to realize data flow between information system platforms through middleware.

3.2.2. Document Management. The first consideration of the design platform is to serve the project personnel, who design the project through professional design software and compile the project management documents with office software. The design software includes AutoDesk software and Bentley software; the office software includes Microsoft Office and Adobe Reader [16]. There are many kinds of applications where many formats of files have been produced, and these files are scattered in the minds of project personnel, which requires a compatible platform. The files of the whole project are stored in the project directory according to certain rules, which can be accessed by project personnel with project authority, thus improving the security, accuracy, and timeliness of project information, as well as the communication efficiency of project participants.

For files about co-design of cave dwellings on the platform, fuzzy search can be performed by file name, or advanced search can be performed by file attribute [17] which is convenient for users to find the required files quickly when they are unfamiliar with the project folder structure.

3.2.3. Standardize Design Standards. Project design documents are designed by the professional designers who participate in the project according to the distribution of project work packages, so it is necessary to formulate a unified project rule to constrain the project personnel to carry out standardized work [18]. The design platform needs to set template files and document coding rules and unify the file design and naming requirements of project personnel so as to realize the standardization of design documents.

3.2.4. Collaborative Design. The co-design management platform of cave dwellings needs to integrate design software, office software, and so on so as to read files on the design platform for editing and modification or read files for editing and modification in software [19]. Reference design is needed between upstream and downstream disciplines. Once the file path is changed in Windows, its reference will be invalid. The management platform should support the reference relationships between design documents and maintain relationships of these dynamic reference [20]. Design files will generate multiple versions of files due to design problems or external condition table updating. In file reference design, it is necessary to support the file to automatically update the reference content with the version, that is, the latest version of the reference file.

3.2.5. Process Management. The co-design platform of cave dwellings should have the function of document flow management, display the current process status of documents, support serial processes and parallel processes, and realize the associated setting of workflow and role permissions [21]. When the status of the document changes in the process, it needs to get the function of reminding and guiding so that the annotation information in the process of document circulation can be saved and can be viewed at any time.

3.2.6. Real-Time Update of Data. After the project personnel upload or update the document, it can be read in real time by other personnel with access rights. The server should support distributed storage management, ensure that the project team members in different places can access the latest data in real time, eliminate geographical restrictions, and provide the functions of local cache and incremental transmission in different places. At the same time, it is also necessary to support flexible timing synchronization of project documents in different places.

3.2.7. Project Data Security. The account of the company's design management platform uses Windows domain account to realize single sign-on. The external cooperators of the company are assigned to log in with the new platform account [22]. There are many project participants, and under the premise of sharing project documents, it is also necessary to ensure the safe access and storage of information content. The design of the management platform needs to satisfy the login of account password and assign appropriate permissions according to the role of the project so as to prevent users from viewing some unauthorized project files, which can ensure data integrity from being used by unauthorized users, ensure that unauthorized users cannot make unauthorized modifications to data, and ensure that users with permissions can access data and resources timely. In addition to authentication, it is also necessary to encrypt the transmission of project files to ensure the safe transmission of data on LAN and Internet.

3.2.8. Platform Access. The co-design management platform of cave dwellings needs to provide data management and storage on the server side, which provides the access to the server through the client side. In addition to carrying out collaborative work, it is also necessary to meet the needs of collaborative work on the Internet and with proxy server to publish to the Internet to ensure data security [23]. For multiple workplaces, multisite expansion deployment can be realized, where LAN and Internet users all obtain access of desktop client and browser.

3.3. Nonfunctional Requirements of the Platform. On the premise of meeting the functional requirements of the information system, the co-design management platform of Henan cave dwellings studied in this paper also needs to meet the nonfunctional requirements, such as rapid response and stable operation of the platform. Nonfunctional requirements are mainly reflected in the following aspects:

(1) *Response Time*. When platform users edit or view folders and documents, the reading of documents should be presented to users within the acceptable range of users, and the response time should be less than 1 s.

(2) *Number of Concurrent Users*. When a large number of users access the platform at the same time, the platform needs to have good concurrent processing ability to meet the processing requests of a fixed number of users [24]. This research requires that the platform can carry at least 200 users.

(3) *Ease of Use*. The interface is simple and operation is simple, while the structure is clear. The client can use it after simple training.

(4) *Maintainability*. The co-design management platform of cave dwellings has an independent maintenance interface, which can set and maintain the platform to meet the configuration requirements of client users [25].

(5) *Disaster Tolerance*. The platform needs to have a certain disaster tolerance capability, and it needs to have an automatic recovery function when encountering unexpected situations, such as fire and earthquake.

(6) *Extensibility*. The platform needs modular architecture, and the modules have strong independence [26]. It can select functional modules according to users' requirements, otherwise expand the use function by adding modules, and it will not affect use with the expansion of requirements which integrates with other information systems to realize data interaction.

4. Design of the Platform

4.1. Overall Structure. The co-design platform database of cave dwellings is used to store the platform directory, users, permissions, attributes, processes, and other information, and the file server is used to store the files. In addition, the platform is applied to project personnel, and the interaction between the client and the server is connected to realize the functions of user login, permission control, file reading, system maintenance, and so on. The application layer is responsible for content display and provide clients for users to send and receive commands. The application layer uses the integration server and file server to interact with the database and file storage devices [27]. When the application layer sends instructions, the integration server and the file server are responsible for transmitting the instructions to the database and the file storage device, respectively. When that database and file storage device send the original data, the integration server and file server interpret it and send it to the application layer [28]. The logic architecture diagram of the platform is divided into three layers: application layer, logic layer, and data layer, as shown in Figure 3.

Considering that the project personnel are scattered in different office locations, the platform can be accessed on both LAN and Internet, and the efficiency of access should be considered. The form of coexistence of platform C/S and B/S mode is selected, which effectively solves the need of designers to carry out the co-design of cave dwellings through platform client in the company. At the same time, it also solves the need for the personnel of different project departments to access shared files through browsers.

4.2. Specific Design

4.2.1. Functional Design. According to the demand analysis, the functions of co-design platform of cave dwellings are divided into four blocks: environment configuration, co-design of cave dwellings, drawing proofreading, and data storage of cave dwelling patterns. The design diagram of the main function tree of the design platform is shown in Figure 4.

In the environment configuration, multiple data sources can be created, and each data source can include multiple projects [29]. Administrators log in to a data source, synchronize Windows domain control users, create new logical users for the use of project partners, and set up project roles for all users. Figure 5 shows the relationship among data sources, projects, and accounts on the platform.

A Design Institute already has a project management system, but the API interface of this system is limited, so it can only provide data values and cannot import data. Therefore, the project management system data outputs them to the design management platform in one direction. In addition, this platform needs to realize the synchronization of project architecture and project attribute data from the existing project management system through secondary development so as to achieve data synchronization between the platform and the project management system [30]. Because the project management system does not open the corresponding API, this development only realizes one-way data transfer from the project management system to the design management platform and realizes one-way data transfer through intermediate files.

In collaborative design of cave dwelling patterns, users can integrate, read the documents on the platform, and edit and update the contents of the documents according to the design software of this major. When the documents encounter an upgraded version, they can update the version of the documents through version management and keep the latest version as an active editable version. At the same time, in the process of design, collaboration among specialties can be carried out by referring to the design, and the content of platform documents about cave dwelling patterns can be shared in real time to improve the collaboration efficiency among specialties [31]. Users can also communicate project information in time through message service on the platform, customize document attributes according to the needs of the project, and search documents through basic attributes of documents. After the final assembly model is generated, it can be converted into a lightweight file called i-Model for collision check and calibration.

During the process, it is necessary to review the drawings and documents of cave dwelling patterns, which is a mandatory requirement in design management. Usually, it is necessary to carry out intradiscipline audit, interdiscipline fund raising, and interdiscipline countersignature and change the process status by setting judgment conditions. If there is any modification, it will be returned and submitted for review again until it is approved. The whole audit process is carried out on the platform, and the review is recorded to facilitate the subsequent ISO review.

In the safe storage of data, it is required to store data centrally and view the operation records of the platform to meet the needs of various access modes in different places, and the influence on the bandwidth in the process of document transmission ought to be considered. Through the distributed storage deployment architecture in different places and the incremental document transmission technology, the requirements of the platform data transmission on the network bandwidth can be reduced, which improves the efficiency of collaboration in different places.

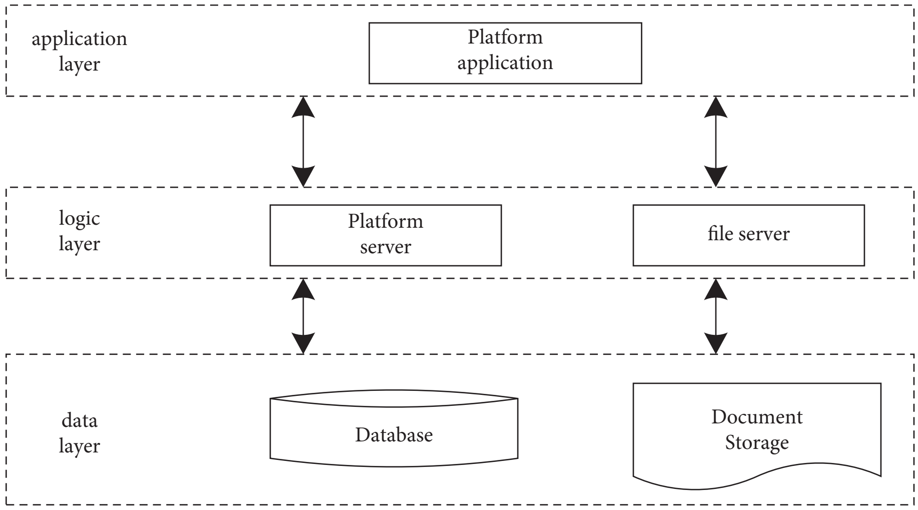

Figure 3: Logical architecture diagram of architectural design management platform.

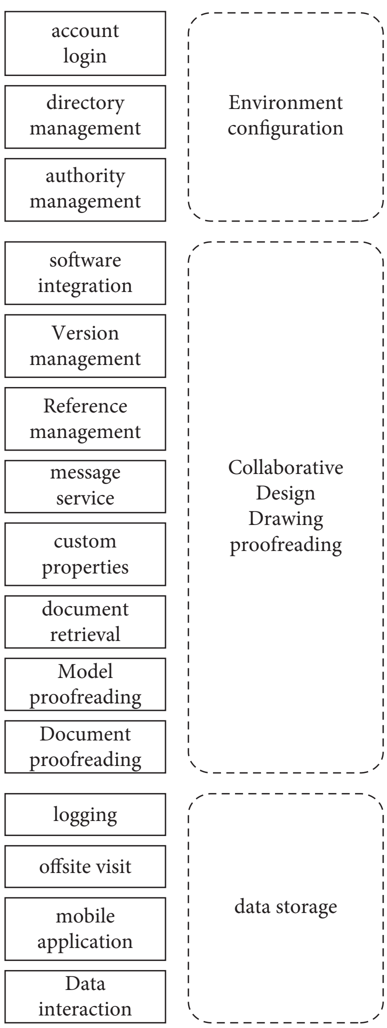

Figure 4: Function tree diagram.

4.2.2. Mechanism of Data Storage. Centralized management of cave dwelling patterns documents distributed on project personnel's computers ensures the unified control of project contents, while real-time synchronization of data can make project participants get the latest information, which improves the efficiency of collaborative work *i*.

With the platform under database + file storage mode, the project files are stored in the server, while the relationships between files and attribute *i* are stored in the database [32]. Multiple projects under one data source can be managed, and multiple projects under separate data sources can be achieved by establishing multiple data sources.

The designer's client adopts the standard client/server (C/S) access mode, which meets the high-performance collaborative work requirements of designers. For the external participants of the project, project site personnel, or business travelers, the browser/server (B/S) access mode is adopted to meet the needs of project document sharing without installing any application programs. At the same time, it provides access methods for mobile devices, including mobile phones and tablet computers, and provides engineers with the function of accessing project-wise data anytime, anywhere.

(1) Audit Management. All users' operations on the document, including username, operation action, operation time, and user's additional annotation, will be automatically recorded by the platform, which is convenient for users to review and track later.

(2) Data Storage. The platform data storage adopts the scheme of combining relational database with file system in Windows, which unifies the storage access mode and can support the storage of multiproject data in multidata sources.

File storage about cave dwelling patterns adopts NTFS (New Technology File System), which is the default of Windows server. It is a disk format specially designed for network, file encryption, and other security features, which supports long file names, data protection, and data recovery. Considering the economic cost of storage, the file storage server of the platform is not set up separately but is deployed together with the integrated server.

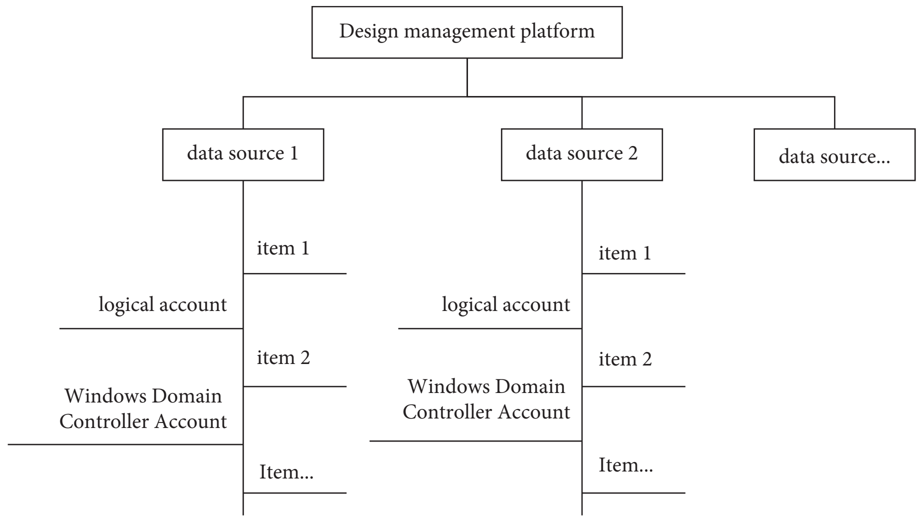

Figure 5: Diagram of data source design.

Database storage supports SQL Server and Oracle to store structured data. By creating an association between project-wise and database through ODBC and employing it to create a new project-wise data source, it provides access for clients. The database stores the account information, document attributes, folder attributes, workflow, application relationship, platform settings, and other contents of the platform.

(3) Remote Cache Technology. In order to improve the speed of users visiting the server in different places, a cache server can be deployed in different places to store local copies of documents. Through the association of storage areas, there are many storage areas in the data source, each storage area is located on a different computer, and real-time data synchronization is realized through the network.

Data synchronization between remote servers and local servers will take up much network resources. In order to reduce the network load, the real-time synchronization of a large amount of data in different places is realized by using the technology of Delta File Transfer, DFT). When a user reads a document, the platform will query the cache server to determine whether the latest copy of the document is on the cache server. If the cache copy does not exist, then the cached copy will be transmitted from the server to the client; at the same time, if the cached copy is out of date, only the modified part of the document will be transferred to optimize the document transfer. Similarly, when a user uploads an updated document, only the modified part of the document is transmitted, which greatly reduces the number of network transmissions and improves the efficiency of network access.

4.2.3. Database Design. Project-wise supports SQL Server and Oracle database, and SQL Server has been used as the database of company information system in A Design Institute, so the database of this platform still select SQL Server.

According to the co-design platform of cave dwellings business analysis of the defined object, its responsibilities can be fully described from the defined data items where an object has only one responsibility. Minimizing the data redundancy of the table ensures the accuracy of the data and effectively improves the performance. In this paper, the database is divided according to the platform components, and the tables of different components are related by the primary keys of the related tables to ensure the independence of tables corresponding to components and facilitate the reconstruction of table structure in secondary development.

The platform database mainly includes four data tables: the main function table of the platform, including users, project folder creation, document storage area, and documents. Set the relational database in the database, as shown in Figure 6.

Because of the huge database design of the co-design platform of cave dwellings, this chapter only lists some contents, such as creating users, creating projects, creating documents, setting processes, accessing records, message boxes, and so on. In addition, the platform creates new users, stores user information, and gives users initial permissions. While in the process of creating new projects and documents, the system records its corresponding attribute information, sets the storage path, and can add project attributes and set project personnel permissions. Afterwards, the users can set the process for the document and carry out the process flow. In the process of document review, the system records the actions and information of the operator and triggers a message box in association with the corresponding documents and notices to inform the corresponding agents. All operations in the platform are recorded and can be viewed at any time.

Finally, add new database tables used in secondary development, such as user-defined design attribute module table, which mainly defines project folders and their attributes; the user-defined module of drawing review process mainly defines status, process, process status approver,

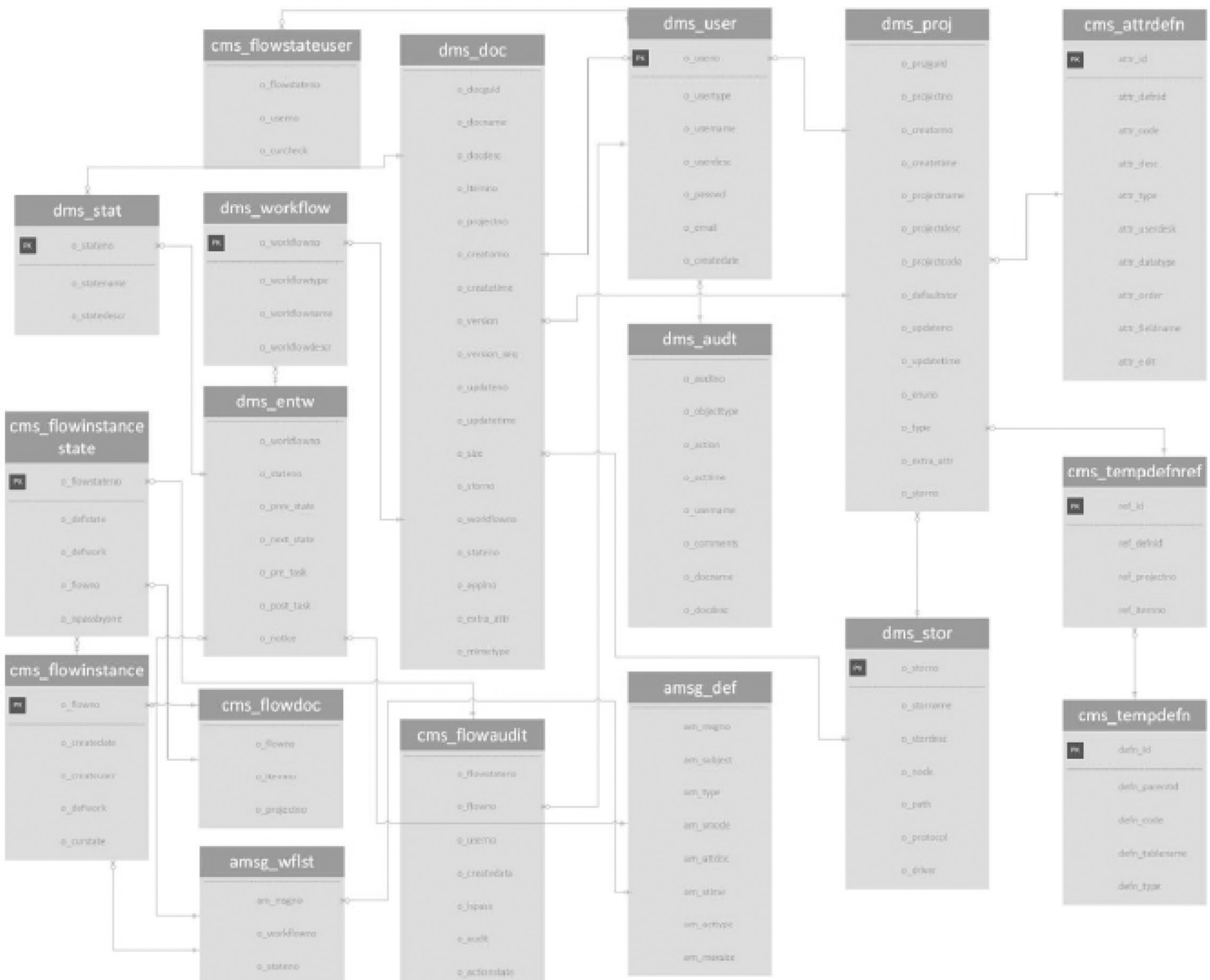

Figure 6: Database diagram.

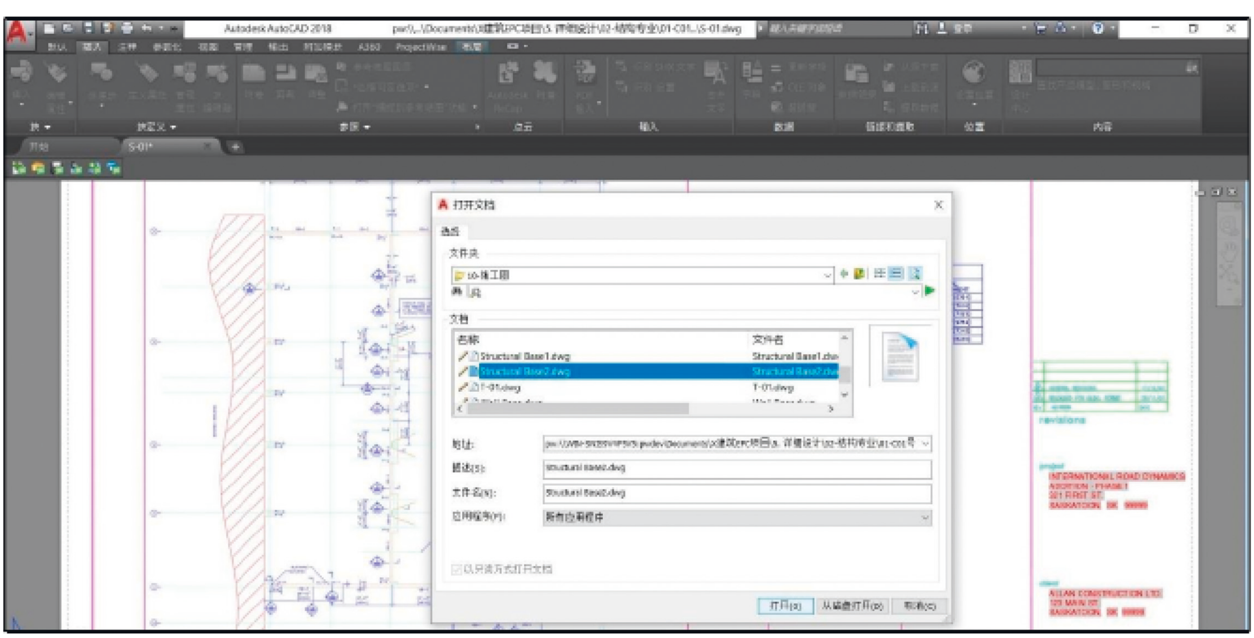

Figure 7: Input of project document diagram.

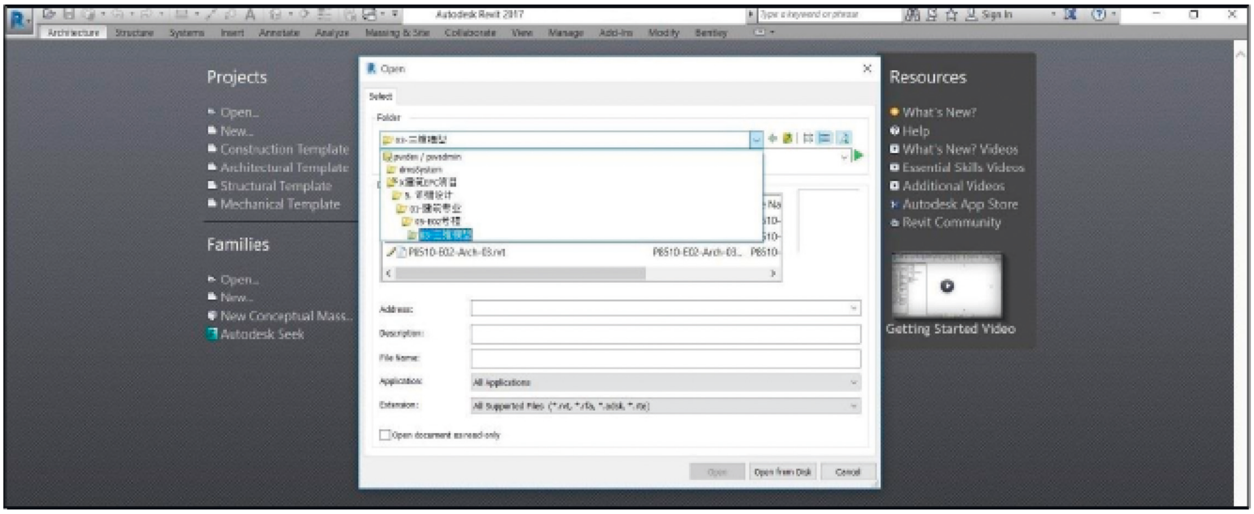

Figure 8: Integration page.

Table 1: Function tests.

Test function	Test methods and test steps	Test Results
User login	The user enters the user name and password to test the system login function	Pass through
Configuration management	Create a new data source, set the network connection method, set the system permissions, configure the process, configure the environment properties, configure the message box, configure the application	Pass through
User settings	Create new users and synchronize domain control users. User account creation, import, and synchronization are all normal	Pass through
New project	Import project schemas, plans, and properties. Import the MPP document exported from the project management system on the platform. According to the import steps, the content is imported normally	Pass through
Folder management	Operates on the folder menu. New, open, copy, cut, paste, rename, delete operations are normal	Pass through
Document management	Operates on the document menu. New document, new version, open, copy, cut, paste, rename, start process, delete are normal	Pass through
Application integration	After installing the integrated plug-in, the corresponding documents on the project-wise platform can be opened in MicroStation, AutoCAD, and Revit software and the reference documents can be read. Double-clicking a document on the platform can launch the corresponding application to perform operations such as checking out, editing, and checking in. You can also select documents on the platform to perform operations such as checking out, editing, and checking in in the application. It is verified that the integration of platform and software is bidirectional	Pass through
Reference design	In the design software, through the "file link" method, select the file on the platform to carry out the reference design, and the referenced document is only displayed and cannot be modified	Pass through
Publish *i*-Model files	Publish final assembly model RVT files and DGN files as *i*-Model files Open a lightweight read-only model; you can browse the model and view build property information, but cannot edit it	Pass through
Drawing review	Select process, select reviewer, transfer status, and submit review comments Every operation and review comments of process submission and rollback are saved for authorized users to view the review process records at any time	Pass through
Model proofreading	The final assembly model performs model collision, annotation, and so on Select the relevant professional components that need to be checked for collision, and the software will automatically start the collision check and list the collision points in the model. Click on a collision point to redline and generate an independent annotation file without affecting the content of the source file	Pass through

process review log record, status and process association, document and process association, and message box and process association.

5. Implementation and Test of Platform

5.1. Implementation of the Platform. Users can normally access the project-wise platform in local area network and other places and carry out collaborative work by logging into the client of the project-wise platform. Every user logs in through his/her personal account. And no matter what kind of network he/she connects to the project-wise platform, the content of the user interface is consistent. it can be selected to insert linked documents on the platform to carry out collaborative design, as shown in Figure 7.

when the plug-in is installed, the "Bentley" column is displayed in the menu of Revit software. Click the "Open" button, and a login dialog box of the design management platform will pop up. After logging in, users can select the document of the design management platform to open and carry out model design, as shown in Figure 8.

5.2. Testing of the Platform. Through detailed tests of various system functions of the system, the test results are all passed, as shown in Table 1.

6. Concluding Remarks

In recent years, with the acceleration of urbanization, the domestic construction industry has experienced a period of rapid growth. The huge inefficiency and waste in the construction industry make people consider how to reform the production mode and organization mode of construction projects. With the development of cloud environment, the concept of collaborative design came into being. By applying to the co-design of cave dwellings, it is able to effectively deal with various data in the design stage and strengthen the communication between designers. In this paper, the collaborative design methods under the building cloud platform are combed in detail, and the platform is designed and implemented. Finally, the results of tests are excellent.

Data Availability

The dataset can be accessed upon request to the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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Research Article

Anti-UAV High-Performance Computing Early Warning Neural Network Based on PSO Algorithm

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In order to effectively solve the problem that the radar detection system is difficult to detect the "low, small, slow" UAV, the high-performance computing early warning neural network is used to recognize the air UAV in real time and extract the target category and image space location information; the PSO algorithm is used to optimize the parameters of the anti-UAV to ensure that the anti-UAV not only relies on factors but also fully combines the dependence of the visual field factor to quickly obtain the optimal solution through analyzing the high-performance computing early warning neural network in this paper. This algorithm is used to initialize the anti-UAV resources and improve the global optimization capability of the algorithm proposed in this paper. Finally, the experimental results show that the proposed PSO algorithm has better high-performance computing early warning performance to meet the actual needs of network high-performance computing early-warning neural networks.

1. Introduction

With the continuous development of anti-UAV high-performance computing early-warning analysis technology, the ways for people to obtain anti-UAV high-performance computing early warning information are also increasing. Among them, relying on its huge information content, the anti-UAV high-performance computing early warning technology can be used to share resources. By using the computer Internet, the anti-UAV high-performance computing early warning information you need can be obtained. Although users themselves can use the anti-UAV high-performance computing early warning to quickly obtain relevant data, the required data information cannot be achieved by the general browsing and query methods due to the huge amount of data information [1, 2]. In order to effectively solve this problem, Anti-UAV high-performance computing early warning technology came into being. This technology can speed up the user's access to data information, although the required data information is still not accurately obtained under such conditions. The conventional recommendation method has greatly reduced the accuracy of Anti-UAV high-performance computing early warning when processing batch data information requests. In the anti-UAV high-performance computing early warning information environment, the target information data can be obtained from the massive data information and sent to the target user simultaneously to determine the development direction of the anti-UAV high-performance computing early warning.

Regarding the shortcomings of the traditional anti-UAV testing method, the PSO algorithm calculation method in the anti-UAV detection method is adopted, the code characteristics in the detection method are compared with the true characteristics of the notified safety defects, and the similarity matching degree is used to check the Anti-UAV code for defects [3]. This method can be used to better improve the accuracy and work efficiency of detecting defects, and deal with the situation that the current anti-UAV detection method cannot quickly deal with the legacy anti-UAV and the complex structure of the anti-UAV [4]. Real-time analysis of the UAV flight trajectory in the continuous time domain is performed through the PSO algorithm to obtain the predicted trajectory results of the corresponding

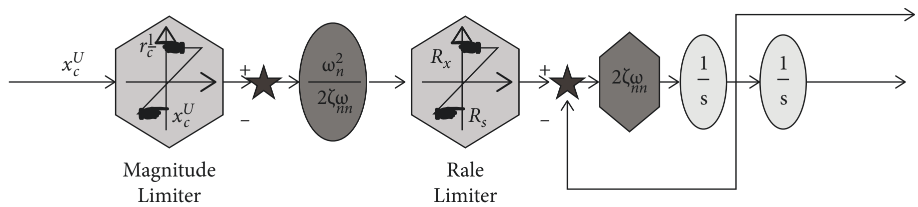

Figure 1: Structure diagram of the second-order control system. The state expression force of the second-order reference model.

UAV in the next stage and realize the full monitoring and prediction of the flight behavior of the UAV in the air. This method has high computational real-time and accuracy and can give anti-UAV capabilities to airports, military units, no-fly zones, and other important venues in the field of machine vision [5–8].

2. Method and Material

2.1. Mathematical Model of UAV Motion. In order to accurately reflect the motion state of the UAV and facilitate the simulation calculation, the impact of the UAV's elasticity is not considered, and the Earth is assumed as an inertial reference frame, ignoring the influence of the curvature of the Earth in this paper [9]. Establish a three-degree-of-freedom model of the UAV.

The motion equation of the UAV in the ground coordinate system is as follows:

$$\begin{cases} \dot{x} = V \cos\gamma \cos\beta + \omega_x, \\ \dot{y} = V \cos\gamma \sin\beta + \omega_y, \\ \dot{z} = V \sin\beta + \omega_z. \end{cases} \tag{1}$$

The motion equation of the UAV in the track coordinate system is as follows:

$$\begin{cases} \dot{V} = \dfrac{T\cos\alpha - D}{m} - g\sin\gamma - \dot{\omega}_x\cos\gamma\cos\beta - \dot{\omega}_y\cos\gamma\sin\beta - \dot{\omega}_z\sin\beta, \\ \dot{\beta} = \dfrac{(L + T\sin\alpha)\sin\varepsilon}{mV\cos\gamma} + \dfrac{\dot{\omega}_x\sin\gamma}{V\cos\gamma} - \dfrac{\dot{\omega}_y\cos\beta}{V\cos\gamma}, \\ \dot{\gamma} = \dfrac{(L + T\sin\gamma)\cos\varepsilon}{mv} - \dfrac{g}{V}\cos\gamma + \dfrac{\dot{\omega}_x\sin\gamma cos\beta}{V} + \dfrac{\dot{\omega}_y\sin\gamma\sin\beta}{V} - \dfrac{\dot{\omega}_z\cos\gamma}{V}, \\ \dot{Q} = \omega_z\cos\varepsilon + \omega_y\sin\varepsilon, \end{cases} \tag{2}$$

where, (x, y, z) is the position of the UAV; V is the flying speed of the UAV; α is the angle of attack; ε is the roll angle; γ is the flight path angle, and β is the course angle; Q is the pitch angle; T Expressed as the UAV thrust; D is the drag force; L is the lift force; m is the mass of the unmanned position: g is the acceleration of gravity; $(\dot{\omega}_x, \dot{\omega}_y, \dot{\omega}_z)$ and $(\omega_x, \omega_y, \omega_z)$ are the components of wind acceleration and wind, respectively, on the three coordinate axes.

In order to better adapt to the requirements of UAV control stability, it is necessary to further consider the speed and bandwidth constraints of state quantity and input quantity in the control system design process. The difficulty of this problem lies in how to mathematically describe the speed and bandwidth constraints of the control commands in the actual system. Therefore, a second-order reference model with nonlinear links is introduced to reflect the response characteristics of the actual system to control commands. The second-order reference model structure with amplitude, speed rate, and bandwidth constraints is shown in Figure 1.where sat$(\cdot)$ is the saturation function; x_c^0 is the input commands; x_c is the output command; x_c^L is the upper limit amplitude constraints of the command, x_c^U is the lower limit amplitude constraints of the command; $\pm R_x$ is the speed constraints of the command; ζ_n and ω_n are the damping ratio and natural frequency of the second-order reference model, respectively frequency, according to these two parameters, the command bandwidth constraint is as follows:

$$\omega_b = \omega_n\sqrt{1 - 2\zeta_n\omega_n + \sqrt{2 - 4\zeta_n^2 + 4\zeta_n^4}}. \tag{6}$$

$$E_c = \mathrm{sat}\left(x_c^0, x_c^L, x_c^U\right) - x_1, \tag{3}$$

$$E_c' = \mathrm{sat}\left(E_c, -\frac{2\zeta_n R_x}{\omega_n}, \frac{2\zeta_n R_x}{\omega_n}\right), \tag{4}$$

$$\begin{aligned} \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} &= \begin{bmatrix} 0 & 1 \\ 0 & -2\zeta_n\omega_n \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ \omega_n^2 \end{bmatrix} E_c', \\ \begin{bmatrix} x_c \\ \dot{x}_c \end{bmatrix} &= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}, \end{aligned} \tag{5}$$

When the second-order reference model is introduced into the control system design process, the input of this link is the input quantity to be designed $\gamma_c^0, \alpha_c^0, Q_c^0$, and the output of this link is the executable control quantity γ_c, α_c, Q_c. In the meantime, the second-order reference model link can also provide the derivative γ_c, $\dot{\alpha}_c$, $\dot{Q}_c\}$ of the virtual control variable, which can avoid the direct analytical calculation of the virtual control variable. In addition, the introduction of the second-order reference model link greatly improves the autonomy of control-oriented modeling.

2.2. Design of Controller. Assume that the dynamic system of the UAV is a first-order nonlinear system:

$$\dot{x} = Ax + Bu, \tag{7}$$

where

$$\begin{aligned} x &= [x_1(t), x_2(t), \ldots, x_m(t)]^T \in R^m, \\ u &= [u_1(t), u_2(t), \ldots, u_n(t)]^T \in R^n. \end{aligned} \tag{8}$$

They are the status of the flight control system and the input of the controlling quantity; $A \in R^{m\times n}$ is the system matrix and $B \in R^{m\times n}$ is the input matrix simultaneously. The purpose of the control system is to establish a suitable control scheme to ensure that the state vector quality can accurately track the constrained ideal $x_d \in R^{m\times n}$. Define the tracking error as follows:

$$e = x_d - x. \tag{9}$$

In addition, the sliding form surface is expressed as follows:

$$s(t) = e(t) + k\int_0^t e(\tau)\mathrm{d}\tau, \tag{10}$$

where $k = \mathrm{diag}(k_1, k_2, \ldots, k_m) \in R^{m\times m}$ is a nonzero positive definite matrix. If the UAV is under ideal conditions, the various parameters of the system are known and constant. The ideal controller can be designed as follows:

$$u^* = B^+[-Ax + \dot{x}_d + Ke]. \tag{11}$$

Among them, $B^+ = (B^T B)^{-1}B^T$, substituting equation (11) into equation (S) to get the following equation:

$$\dot{e} + Ke = 0. \tag{12}$$

In the above formula, if K satisfies the Huiwitza polynomial when t tends to infinity $\|e\| = 0$. However, the mathematical model of the system cannot be accurately obtained, and the UAV will be subject to parameter perturbation and external interference during flight. The controller based on sliding mode control cannot deal with the influence of these uncertain factors well. Therefore, it is necessary to design an intelligent, Robust control system to achieve accurate tracking of the flight trajectory. At the same time, the system must have a certain anti-interference ability.

The design of the intelligent control system is shown in Figure 2.

The identification of the system and the approximation of the function can be realized through a pure wavelet neural network, and this will also lead to other problems, such as the expansion of the network structure. In addition, the recurrent neural network can realize the identification of nonlinear systems, but it is not stable enough and the learning algorithm is also more complicated. The controller based on the PSO algorithm can not only solve the stability problem but also approximate the ideal mathematical model and reduce the dependence on the mathematical model.

The purpose of this paper is to reduce the high-performance computing early warning neural network overhead of the underlying network under the premise that the underlying network resources are limited, and path segmentation is not supported. A binary combinatorial optimization model for the anti-UAV high-performance computing early warning neural network problem is established.

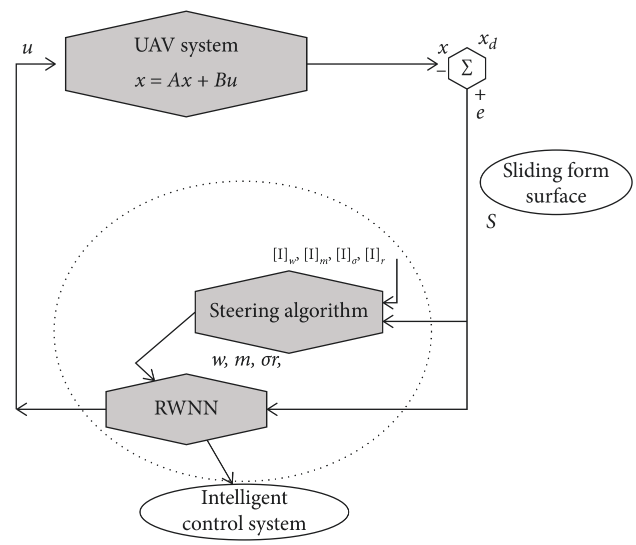

Figure 2: Intelligent control system structure.

First, define the remaining available CPU and memory resources of the underlying node $n_S \in N_S$ as $\mathrm{cpu}'(n_S)$ and $\mathrm{memory}'(n_S)$, respectively, and the remaining available bandwidth resources of the underlying link $e_S \in E_S$ is $b'(e_S)$.

$$\begin{aligned} \mathrm{cpu}'(n_S) &= \mathrm{cpu}(n_S) - \sum_{\forall n_V \perp n_S} \mathrm{cpu}(n_V), \\ \mathrm{memory}'(n_S) &= \mathrm{memory}(n_S) - \sum_{\forall n_V \perp n_S} \mathrm{memory}(n_V), \\ b'(e_S) &= b(e_S) - \sum_{\forall e_V \perp e_S} b(e_V). \end{aligned} \tag{13}$$

Among them, $n_V \perp n_S$ is defined that the virtual node n is allocated to the bottom node n, and $e_V \perp e_S$ is defined that the virtual link n is allocated to the bottom links.

The available bandwidth of any path $P \in P_S$ is expressed as the minimum remaining bandwidth along the path between two lower-level nodes.

$$b(P) = \min_{e_S(i,j)\in P} b(e_S(i,j)). \tag{14}$$

Let M_N be a binary $m \times n$ matrix, which represents the high-performance computing early warning relationship of the node. Each row vector and column vector represent a virtual node and the underlying node, $m = N_V|$, $n = |N_S|$, When the virtual node n_V^i is assigned to the bottom node n_S^i, the value of $M_N(i,j)$ is 1. Otherwise, it is 0. For the same anti-UAV request, each virtual node can only be assigned to one bottom node, and two virtual nodes cannot be assigned to the same bottom node simultaneously. The constraint conditions are formalized as follows:

$$\begin{aligned} &\sum_i^m M_N(i,j) \le 1, \quad j \in \{1, 2, \ldots, n\}, \\ &\sum_j^n M_N(i,j) \le 1, \quad i \in \{1, 2, \ldots, m\}. \end{aligned} \tag{15}$$

The remaining available CPU and memory resources of the underlying node n_S^j need to be able to meet the needs of

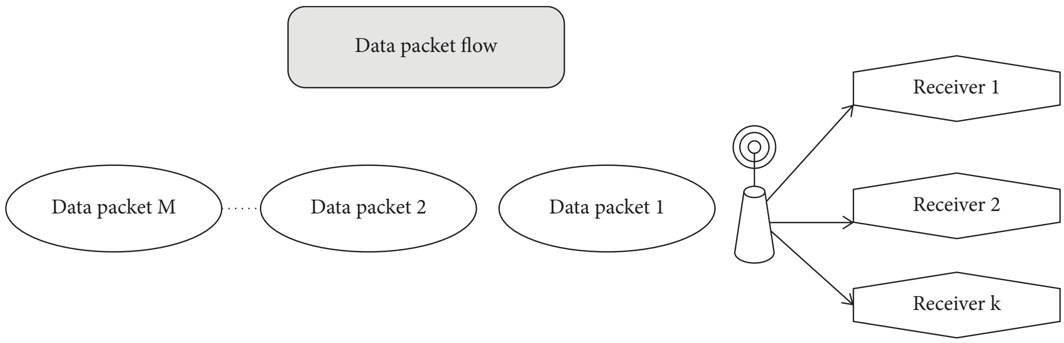

Figure 3: System model.

the virtual node n_V^i, and the node is within the constraint range of the requested location of n_V^i, before n_V^i can be alerted to the underlying node n_S^j by high-performance computing. The distance between nodes n_V^i and n_S^j is represented by Euclidean distance dis (). The remaining available CPU and memory resources of the underlying nodes and the node constraints are, respectively,

$$\begin{gathered}M_N(i,j)\left(\mathrm{cpu}'\left(n_S^j\right)-\mathrm{cpu}\left(n_V^i\right)\right)\geq 0,\\ M_N(i,j)\left(\mathrm{memory}'\left(n_S^j\right)-\mathrm{memory}\left(n_V^i\right)\right)\geq 0,\\ M_N(i,j)\times\mathrm{dis}\left(\mathrm{loc}\left(n_V^i\right),\mathrm{loc}\left(n_S^j\right)\right)\leq D_V^i,\end{gathered}\tag{16}$$

where, $M_N(i,j)\in\{0,1\}$, $i\in\{1,2,\ldots,m\}$, $j\in\{1,2,\ldots n\}$.

The anti-UAV high-performance computing early warning neural network model in this paper is shown in Figure 3 [10].

(1) The system model includes a source node and K ($K>2$) receiving nodes are configured, and the packet set needs to be broadcast to K receiving nodes. In this paper, it is assumed that the source node is within a period of time. Broadcast data packet within Δt

(2) The receiving node sends ACK or NAK information to the source node, the source node receives and maintains the feedback matrix table T, $T=(K,N)$, and the matrix element $T(i,j)$ indicates whether the receiving node correctly receives the data packet. Here, $R_iP_j 1\leq i\leq K$, $1\leq j\leq M$.

(3) In short, here, it is assumed that all control messages ACK or NAK are sent instantaneously and are not lost.

(4) The node R_i data packet loss rate obeys the binomial distribution with the parameter of p_i ($i=1,2,\ldots,K$).

In this article, if it is considered that there are n packets of the same size in the network, they need to be sent and to be packeted and expressed $X_1,X_2,\ldots,X_n$. The source node encodes the random linear asynchronous or the packet lost by the receiving node, and the new packet Y_i is expressed as follows:

$$Y_i=\sum_{j=1}^{n}g_{ij}X_j.\tag{17}$$

The coding coefficient g_{ij} $(1\leq j\leq n)$ is a value randomly selected from the defined area F_q. After each receiving node receives n coded packets, it can decode the original packet through the next linear equation.

$$\begin{bmatrix}X_1\\X_2\\\vdots\\X_n\end{bmatrix}=\begin{pmatrix}g_{11}&\cdots&g_{1n}\\\vdots&\ddots&\vdots\\g_{n1}&\cdots&g_{nn}\end{pmatrix}^{-1}\begin{bmatrix}Y_1\\Y_2\\\vdots\\Y_n\end{bmatrix}.\tag{18}$$

The PSO algorithm introduced in this paper is divided into a data broadcast stage and a retransmission stage. The specific steps are as follows:

(1) The source node broadcasts N data packets to K receiving nodes, and each data packet is sent at a certain time interval. The source node establishes a feedback matrix T through the received ACK or NAK feedback information and maintains the update.

(2) The source node enters the retransmission phase after the time $M\Delta t$ after broadcasting N packets. All lost data packets form a set $D=\{X_1,X_2,X_3,\ldots,X_n\}$, and the largest coefficient $M_{\max}$ in the coefficient vector $G=\{g_{i1},g_{i2},g_{i3},\ldots,g_{in}\}$ $(1\leq i\leq M_{\max})$ (selected randomly from the limited domain F_q) is used to encode all the lost data packets to generate $M_{\max}$ coded packet. $M_{\max}$ is the maximum number of lost data packets in all receiving nodes, which is determined by the following formula:

$$M_{\max}=\max_{i\in\{1,2,\ldots,K\}}\left\{\sum_{j=1}^{K}T(i,j)\right\}.\tag{19}$$

(3) After resending the encoded data packet, each receiving node estimates and displays the arrangement of its own encoding vector matrix G. $M_{\max}$ r_i If $r_i\neq N$ means that G has not reached the full arrangement for the node R_i, then the node R_i will notify the source node how many coded packets need to be retransmitted before G can reach the full arrangement. The required coded packets are

expressed through N_i, the specific situation is shown in the following formula [11]:

$$N_i = \begin{cases} N - r_i, r_i \leq N, \\ 0, r_i \geq N. \end{cases} \tag{20}$$

In the formula, $i = 1, 2, \ldots, K$

If the receiving node R_i receives a $M_{\max}$ coded packet in the data retransmission phase, N_i is 0. If the node R_i loses 2 encoded packets, then $N_i = 2$.

(4) The source node updates $M_{\max}$ according to the N_i value fed back by each receiving node and generates $M_{\max}$ coded packet in the new retransmission stage. The algorithm is shown in equation (4).

(5) (3) and (4) are repeated until the vector matrix of all receiving nodes is equal to N. That is $M_{\max} = 0$, if there is no lost packet, the receiving node can use the Gaussian elimination method to decode the original data packet.

The PSO algorithm is based on a complex adaptive system and belongs to a random search algorithm. This is also collective intelligence; everyone works together to solve problems. w belongs to the convolutional neural network group algorithm, which is a more important and changeable parameter and plays an important role in the improvement of the algorithm. If w becomes larger, the speed will become smaller, which is beneficial to the overall retrieval. If you use w to reduce the time, the speed will be shortened, which is good for local search. How to control the value of w and effectively solve the problem is a hot spot in the research process. Related research has proposed a linearly decreasing inertia weight, namely LDW, which linearly changes w to improve the convergence of the algorithm.

$$w = w_{\max} - \frac{t \cdot (w_{\max} - w_{\min})}{t_{\max}}. \tag{21}$$

In the formula: the value of w is $[w_{\min}, w_{\max}]$; t is the current iteration number; $t_{\max}$ is the maximum value obtained.

When w decreases linearly, the initial convergence speed decreases, and then as w decreases, the diversity of the algorithm decreases, and the local optimum is achieved. In this paper, we use a nonlinear weighting method to solve the deficiencies in the convolutional neural network group algorithm.

$$w = w_{\max} - (w_{\max} - w_{\min}) \cdot \ \arcsin\left(\frac{t}{t_{\max}} \cdot \frac{\pi}{4}\right). \tag{22}$$

According to the above formula, when the value of t is small, the approximate value of w is equal, and when the value of w is large, it is very advantageous for global search. In the process of increasing t, w decreases nonlinearly, and the value of w is relatively small, so the good local search ability of the algorithm is ensured, and the global search and local search can be adjusted flexibly. Generally speaking, the best design problem can be solved by using a three-layer structure network. Therefore, a three-layer neural network is used, namely input and output and implicit layers.

(1) Network initialization: Each level has a corresponding right coefficient, and a random small nonzero number is given to realize the threshold initialization of each level and determine the learning speed and neuron excitation function.

(2) Output calculation of each layer. First, realize the input of the sample $X = (x_1, x_2, \ldots, x_n)$ and realize the output of $Y = (y_1, y_2, \ldots, y_n)$, and calculate the neuron output by the following formula:

$$\begin{aligned} H_i &= f\left(\sum_{j=1}^{m} w_{ij} - a_i\right), \quad i = 1, 2, \ldots, q, \\ O_k &= \sum_{i=1}^{q} H_i w_{ki} - b_k, \quad k = 1, 2, \ldots, L. \end{aligned} \tag{23}$$

In the formula: H belongs to the hidden layer output. Number of nodes; a is the threshold activation function; the connection weight of the input layer and the implicit layer. O refers to the output of the output layer. B is the connection weight between the hidden layer and the output layer representing the threshold.

(3) Calculate the error e between the network output O and the expected output O_1.

$$e_k = O_{1k} - O_k, \quad k = 1, 2, \ldots, L. \tag{24}$$

(4) Update network connection and threshold:

$$\begin{aligned} w_{ij} &= w_{ij} + \mu H_i (1 - H_i) x(j) \sum_{k=1}^{L} w_{ki} e_i, \quad j = 1, 2, \ldots, m; \ i = 1, 2, \ldots, q, \\ w_{ki} &= w_{ki} + \mu H_i e_k, \quad i = 1, 2, \ldots, q; \ k = 1, 2, \ldots, L, \\ a_i &= a_i + \mu H_i (1 - H_i) x(j) \sum_{k=1}^{L} w_{ki} e_i, \quad j = 1, 2, \ldots, M; \ k = 1, 2, \ldots, L, \\ b_k &= b_k + e_k. \end{aligned} \tag{25}$$

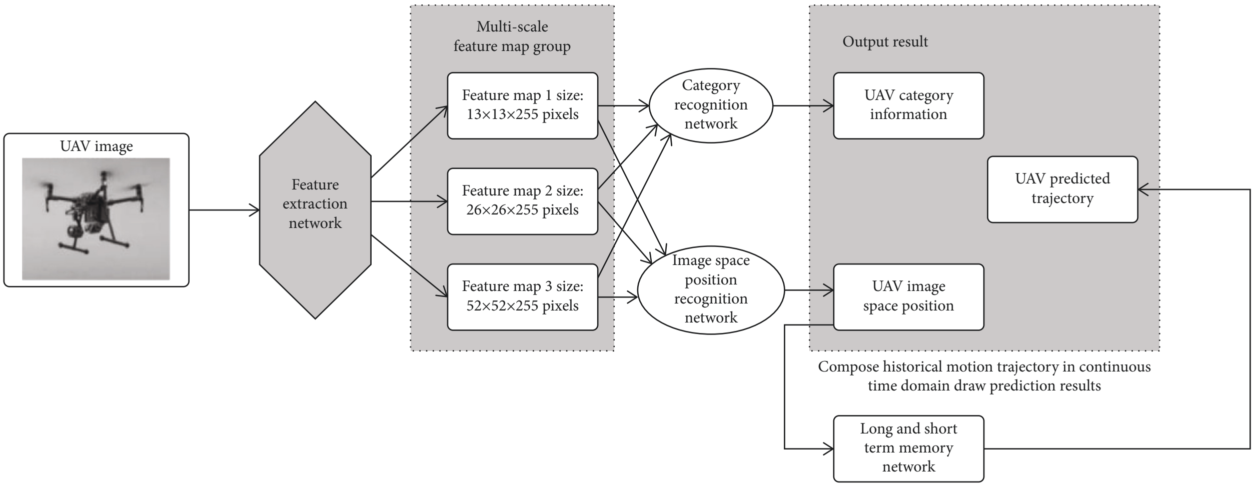

Figure 4: AUNN network structure.

The values of w_{ki} and w_{ij} can be adjusted by the network error e and the above formula, and the values of a and b can also be adjusted by e.

2.3. Composition of System. The designed anti-UAV recognition and trajectory prediction neural network, AUNN). (AUNN) is composed of 4 links of UAV feature extraction, UAV type recognition, UAV image space position recognition, and UAV image space trajectory prediction, as shown in Figure 4.

First, the algorithm can obtain the multiscale deep semantic feature information of the UAV from the aerial UAV image captured by the imaging system through the feature extraction network; Subsequently, the obtained multiscale and high-dimensional feature maps are sent to the UAV type recognition network and the UAV image space position recognition network, to figure out the target UAV category and image space position. According to the change trend of the corresponding UAV's image space position center in a certain time domain, the historical movement trajectory of the UAV in the changed time domain is constructed. Finally, combined with the historical motion trajectory, the predicted motion trajectory of the target UAV in the future time domain is analyzed and output with the PSO algorithm, and the real-time recognition and tracking of the UAV in the current time domain and the trajectory prediction in the future time domain are completed.

Anticipating in the anti-UAV defect inspection, usually based on the behavior of other users in the community, your own participation behavior can be adjusted. According to the above-mentioned user behavior characteristics, the anti-UAV defect detection manager uses incentive guidelines and other methods to reasonably check the anti-UAV defects to improve the user's participation. This kind of management scheme manages the anti-UAV defect detection information resources intelligently. Anti-UAV high-performance computing early warning intelligent management: The anti-UAV defect inspection manager analyzes the user's behavior data and browsing history, and other user resources, explores the needs of users, predicts the user's behavior tendency, and provides users with personalized services that meet their needs, and ultimately realizes the added value of service experience through the organization and regeneration of information.

This article refers to the interactive mechanism model of enterprise knowledge management and service innovation and summarizes the anti-UAV high-performance computing early warning platform model (see Figure 5) to clarify the shortcomings of the anti-UAV, how to configure information, and use data to improve community environment and improve the viscosity of user participation.

The management of any information resource is a process, and the detection of the defects of the anti-UAV consists of several related ordered rings, which constitute the entire organic ring. Intelligent management refers to the analysis of information resources in anti-UAV high-performance computing early warning based on the above three links of resource accumulation, resource arrangement, and resource utilization. Please refer to Figure 6 for the specific process.

It can be seen from Figure 6 that the resource storage ring contains information storage and information collection. In the resource storage link, the anti-UAV system detects the collected anti-UAV defects. The data sorting link includes the sorting of the results of information organization, information analysis, and information data analysis. For target user data, the system data of the mobile phone is analyzed and compared, and in-depth, intelligent operations are taken to make it effective and reasonable. Resource utilization includes a system recommendation link, which classifies and organizes target users through the analyzed data, provides effective and systematic data to corresponding users, and improves resource utilization efficiency.

2.4. Algorithm Implementation. In order to quickly and intuitively obtain the category and location information of aerial UAV, it is first necessary to identify and locate the UAV in the image or video stream data captured by the

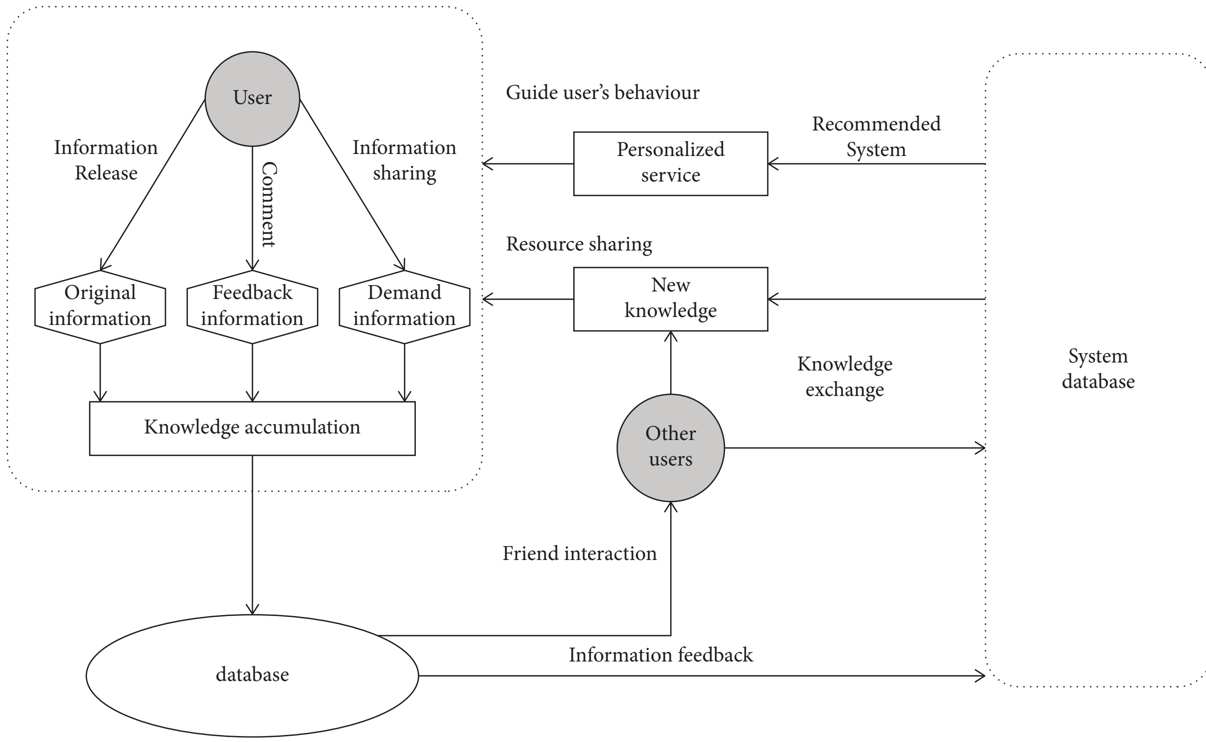

Figure 5: Anti-UAV high-performance computing early warning platform.

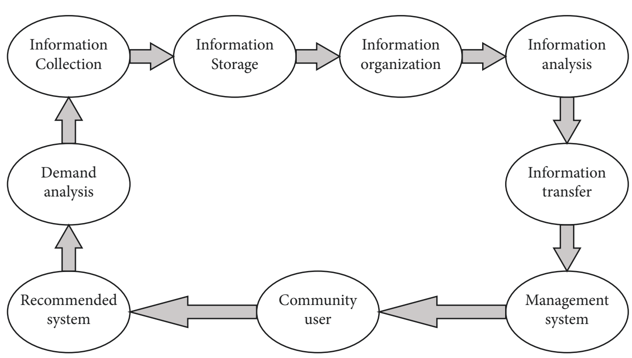

Figure 6: Anti-UAV high-performance computing early warning process.

camera. Orienting at ground-based computing platforms, in view of multiscale and multitarget UAV recognition tasks in the air environment, a UAV Feature Extraction Network (UFEN) is designed as the backbone of AUNN to extract deep semantic information of aerial UAV and use the YOLO V3 (you only look once) target recognition network as the middle layer (neck) and top layer (head) of the AUNN network to complete the target category and image space recognition calculations.

2.4.1. UAV Feature Extraction Network. The UFEN network is a deep residual network, which is composed of a standard convolutional layer, an expanded convolutional layer, and a stack of cyclic residual modules. The network structure of UFEN is shown in Figure 7.

Since the ground-based platform is shooting aerial UAVs, the distance from the UAV to the ground-based detection unit is generally 45 m. At this time, the amount of semantic information in the foreground of the UAV in the image is much smaller than the amount of background semantic information, and the whole colored sky dominates the background. When using the same effective size convolution kernel, the receptive field of standard convolution and the receptive field of expanded convolution is shown in the following equations:

$$r_n = r_{n-1} + (k_n - 1)\prod_{i=1}^{n-1} s_i, \tag{26}$$

$$r_n = r_{n-1} + d(k_n - 1)\prod_{i=1}^{n-1} s_i, \tag{27}$$

where r_n is the receptive field of each unit in the nth convolutional layer; i is the first $n-1$ layer of convolution, the index value of each layer of convolution; k_n and S_i are the size and step size of the convolution kernel of the nth convolutional layer, respectively; d is the expansion convolution coefficient.

By comparing equations (26) with (27), it can be seen that under the premise that the moving step of the convolution kernel is the same as the input image size, the receptive field of expanded convolution in the same layer network is larger than that of standard convolution. For images of aerial UAV, expansion convolution can more effectively obtain the deep semantic features of the image and reduce the multiple redundant calculations of the

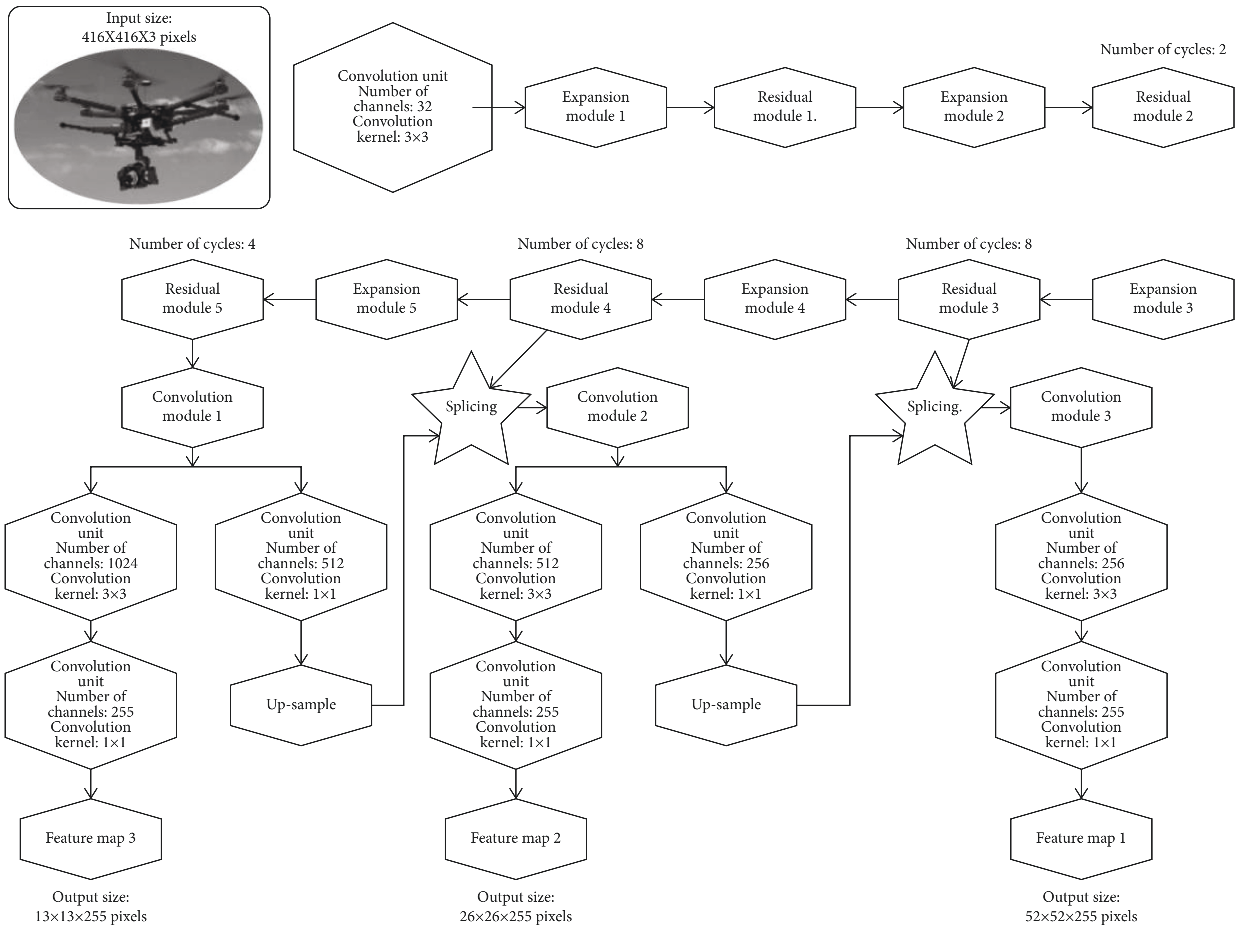

Figure 7: NFEN network structure.

background environment in the standard convolution iteration process. However, due to the discontinuous sampling of the convolution kernel during the calculation process of the expansion convolution, for small aerial UAV targets, the sky dominates loss of spatial hierarchical information, and the inability to reconstruct small object information are prone to occur, as shown in Figure 8(a). In order to solve the above problems, the expanded convolution module with a zigzag structure is used to replace the standard convolution [12, 13] to avoid the expansion convolution kernel with no spatial structure connection to skip or dilute the semantic information points of the UAV. The calculation method of the expanded convolution module with a saw tooth structure is shown in the following formula:

$$\text{Feature} = \text{conv}_{\text{dil}}^{5}\left[\text{conv}_{\text{dil}}^{2}\left(\text{conv}_{\text{dil}}^{1} * \text{input}\right)\right]. \tag{28}$$

In formula (28): input is the input data; Feature is the feature map obtained after calculation; conv_{dil} is the expansion convolution calculation; 1, 2, and 5 are the expansion coefficients. Meanwhile, the expansion coefficient of the high-dimensional expansion convolution is controlled, and the maximum expansion coefficient M_i in the expansion convolution is as follows:

$$M_i = \max\left[M_{i+1} - 2r_i, M_{i+1} - 2\left(M_{i+1} - r_i\right), r_i\right]. \tag{29}$$

In formula (29): r_i is the receptive field of the i-th expanded convolution. The expanded convolution module structure of the sawtooth structure is shown in Figure 9 and Table 1.

After the above mixing and matching, the zigzag structure is fused and convolved, and the full coverage calculation of the feature map information points, as shown in Figure 8(b), is realized. That is, the larger receptive field can be used to extract global semantic information, which also prevents ignorance of target feature information.

When performing deep semantic feature extraction on multiscale UAV targets, due to the continuous deepening of the network and the increase in the number of loop iterations, the size of the feature map will be reduced after each convolution calculation. The small-scale UAV target with less semantic information has a smaller feature map area in each layer. When the network depth is too large, the feature information of the small target will be difficult to be distinguished, and the internal detail texture in the deep semantic information will be weakened. In order to improve the recognition efficiency of small targets, it is necessary to condense deep semantic information and retain shallow feature information [14, 15]. UFEN uses a residual model. Each residual module is composed of two residual units. Each residual unit is shown in Figure 10 including convolutional

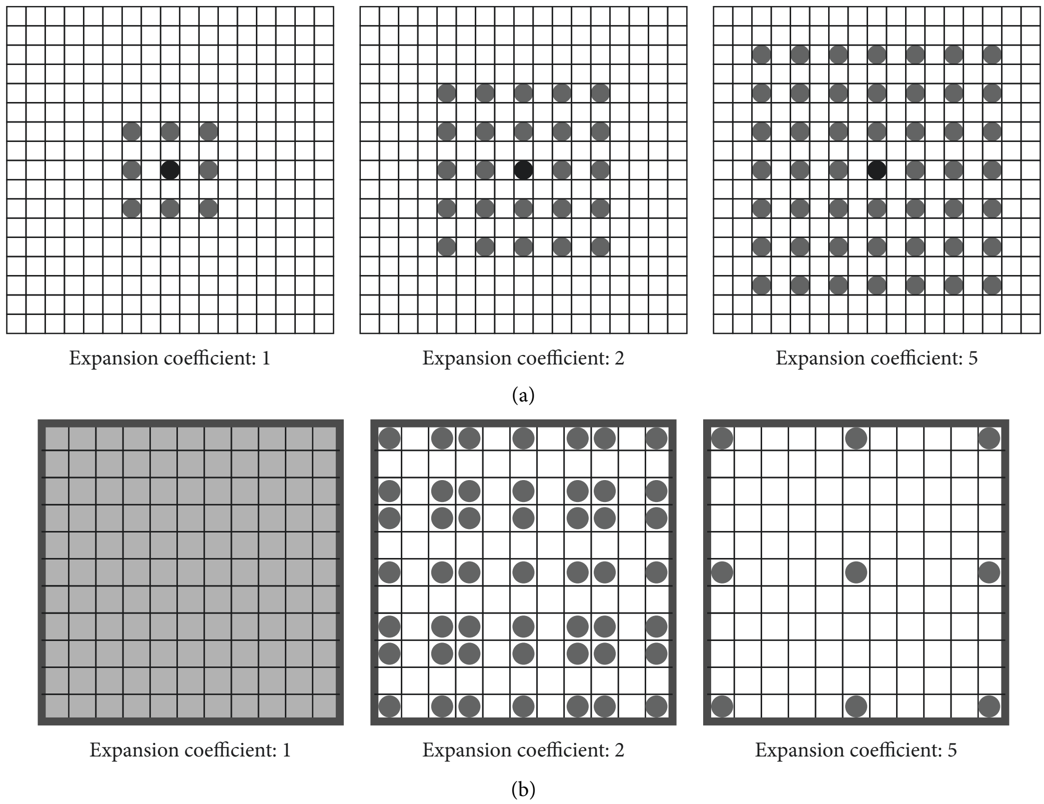

Figure 8: Feature extraction of the expanded convolution module with a sawtooth structure. (a) Standard dilated convolution feature extraction. (b) Zigzag structure fusion convolution feature extraction.

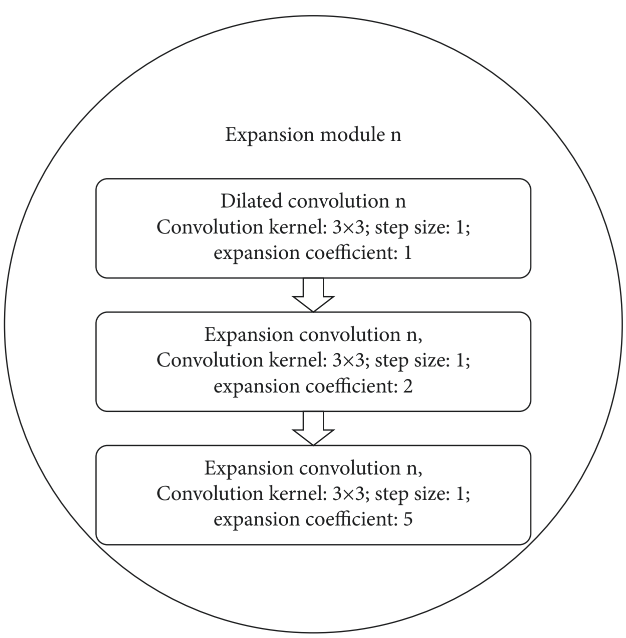

Figure 9: The structural diagram of the expanded convolution module with a sawtooth structure.

Table 1: The number of convolution kernels in each layer of the zigzag structure expansion convolution module.

Number of modules	Level number		
	$n1$	$n2$	$n3$
1	32	32	64
2	128	64	128
3	256	128	256
4	512	256	512
5	1024	512	1024

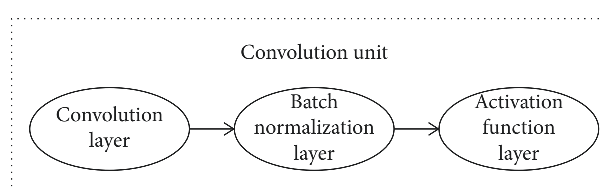

Figure 10: Convolution unit structure diagram.

layer, batch normalization layer, and activation function layer. Among them, the activation function uses Leaky ReLU. Each residual module can integrate the shallow semantic information and deep semantic information inside the module, connect each subsegment network with a shortcut method, integrate large-size, low-dimensional features and small-size, high-dimensional features to improve the accuracy of multiscale target recognition, control gradient propagation, and prevent gradient dispersion or gradient explosion. The residual module structure in UFEN is shown in Figure 11. UFEN has a total of 5 residual modules, which are, respectively, connected to the 5 expansion convolution modules. The first

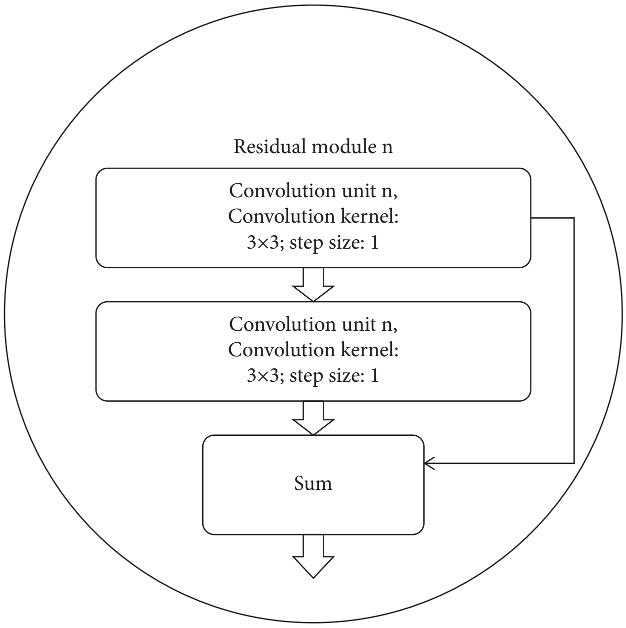

Figure 11: Structure diagram of residual convolution module.

residual unit of the residual module will downsample the picture once and will predict the picture in the last 3 times of downsampling. The cycle times of the 5 residual modules of UFEN are 1, 2, 8, 8, and 4, respectively. The specific number of convolution kernels is shown in Table 2.

Table 2: The number of convolution kernels in each layer of the residual convolution module.

Number of modules	Level number	
	$n1$	$n2$
1	32	64
2	64	128
3	128	256
4	256	512
5	512	1024

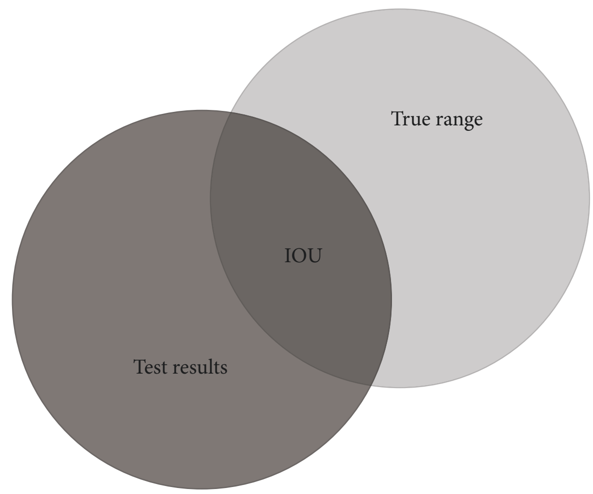

Figure 12: Schematic diagram of IOU.

2.4.2. UAV Target Recognition Network. After UFEN completes the feature extraction of the UAV target and generates 3 feature maps with scales of 13×13, 26×26, 52×52, respectively, AUNN will use the YOLO V3 target recognition network to identify the feature map group.

The YOLO V3 target recognition network will mesh the recognition area on the input feature map, and the number of grid divisions corresponds to the size of the input feature map. The anchor box in each grid in the feature map is responsible for identification and detection, and the information N contained in each grid is expressed as follows:

$$N = \left[b_x, b_y, b_w, b_h, p_0, p_1, \ldots, p_c\right] \times B, \tag{30}$$

where b_x, b_y, b_w, b_h are the coordinates and size information of the central point of the current prediction frame; p_0 is whether the target is included in the current grid and the accuracy of the target location; $p_0, p_1, \ldots, p_c$ is the probability that the target in the frame belong to the type to be identified. If the target center falls in the semantic information pixel point of a certain feature map, the grid will detect the target in this area, B is the number of anchor boxes, and the confidence value Po is the product of the probability of detecting the target and IOU (intersection over union), which is shown in the following formula:

$$\text{confidence} = P(\text{object}) \times \text{IOU}_{\text{pred}}^{\text{truth}}, \tag{31}$$

where P (object) is whether there is a target in the grid. If it exists, the value is 1, and the value is 0 if it does not exist; IOU is the occurring simultaneous ratio, that is, the truth frame truth generated by the target and the range frame pred generated by the target recognition, the expression is shown in the following formula:

$$\text{IOU} = \frac{\text{DR} \cap \text{GT}}{\text{DR} \cup \text{GT}}. \tag{32}$$

In the formula: DR is the detection result; GT is the ground truth, and the result of the intersection of the detection target and the ground truth is shown in Figure 12.

By calculating the IOU between the detection target range frame and the ground truth, the network can distinguish the foreground target from the background target.

For feature maps at different scales, when each divided grid classifies internal targets, it needs to predict the class probability of the internal c targets, that is, the probability of the i-th target falling in the grid $P(\text{Class}_i|\text{object})$:

$$\begin{aligned} P\left(\text{Class}_i|\text{object}\right) &= P(\text{object}) \times \text{IOU}_{\text{pred}}^{\text{truth}} \\ &= P\left(\text{Class}_i\right) \times \text{IOU}_{\text{pred}}^{\text{truth}}. \end{aligned} \tag{33}$$

Each grid in the YOLO V3 network must first calculate whether there is a target inside. When it is determined that a target exists, the classification of the target will be judged according to its category prediction probability. When the target's prediction probability of a certain category exceeds the threshold and is greater than other classification prediction values, the target is considered as the current category.

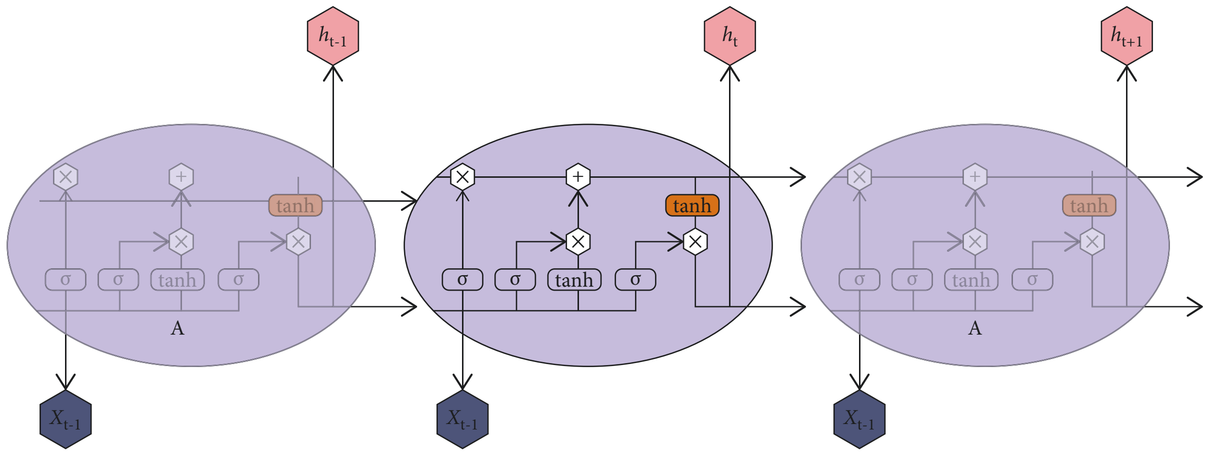

Figure 13: PSO algorithm structure.

For the judgment of the target's position information, YOLO V3 will continuously learn and correct the size of the anchor box through fine-tuning iteratively so that the result of the prediction frame is close to the truth frame. The adjustment process is shown in the formula:

$$\begin{cases} b_x = \sigma(t_x) + c_x, \\ b_y = \sigma(t_y) + c_y, \\ b_w = p_w e^{t_w}, \\ b_h = p_h e^{t_h}. \end{cases} \tag{34}$$

In formula (34): c_x and c_y are the coordinates of the upper left corner of the corresponding grid on different scale feature maps; t_x, t_y, t_w and t_h are the deviation between the prediction box and the truth frame; p_w and p_h are the length and width dimensions of the anchor box, and finally, the coordinates b_x and b_y of the upper left corner of the prediction frame and the corresponding length and width b_w and b_h of the prediction box are obtained.

The UAV trajectory prediction network will take the UAV space historical time domain motion trajectory as input data, use the long and short term memory network PSO algorithm to learn the flight behavior characteristics of the UAV, and use the image space position in the existing time domain to predict the iteratively, position of the image space in the future time domain.

Long and short term memory network is an RNN optimized network that overcomes the problems of gradient explosion and gradient disappearance. Compared with the traditional recurrent neural network (RNN), LSTM has an additional "forget gate" mechanism, which determines whether to forget the content of the moment through the correlation between the input and output at a certain moment and the previous moment, so that only important information is retained in all periods [15]. The structure of the PSO algorithm unit is shown in Figure 13.

x_t is the current UAV image space motion trajectory of input in the time domain; h_t is the UAV image space prediction motion trajectory of output in the next time domain; A is the calculation unit in the PSO algorithm. Each unit is connected from beginning to end, the calculating unit in the same layer will use the output of the previous layer as the input of the next layer; σ (sigmoid) and tanh are the activation functions.

A reshaped trajectory matrix C will be introduced from left to right in the LSTM unit. For the input information at time t, the matrix passed in from the left end in the LSTM unit is C_{t-1}, and the matrix passed out from the right end is C_t. Among them, the C_{t-1} matrix is multiplied by a coefficient by the multiplier, and then linearly superposed by the adder, and finally C_t is obtained.

The h_{t-1} matrix on the left is connected with the input h_t matrix, and the coefficient f_t is calculated by the sigmoid function through a linear unit. The coefficient is the multiplier coefficient in the x matrix transfer process. The expression is shown in the following equation:

$$f_t = \sigma\left(W_f\left[h_{t-1}, x_t\right] + b_f\right), \tag{35}$$

where W_f and b_f are the undetermined coefficients to be learned during the training process. In the "forget gate" of LSTM, if the output of the sigmoid function is 1, the input will be completely remembered; if the output is 0, the input will be completely forgotten; if it is the intermediate value of 0~1, the input will be remembered in proportion.

Finally, LSTM passes the input information through a "forget gate" again to generate an output h_t. h_t generated has two parts. One part is passed to the same layer unit, and the other is passed to the next layer unit. Then the final output predicted trajectory at time t of the LSTM unit is as follows:

$$h_t = \sigma\left(W_t\left[h_{t-1}, x_t\right] + b_t\right) \times \tan hC_t. \tag{36}$$

Through the above calculations, AUNN has been able to obtain the category information and location information of the target UAV, and project the center point of the continuous frame recognition position of the target UAV to the time domain coordinates to obtain the historical time domain motion trajectory of the UAV image space, and use the PSO algorithm to predict the position of the UAV in the future time domain. The feedback flow of the calculation process is shown in Figure 14.

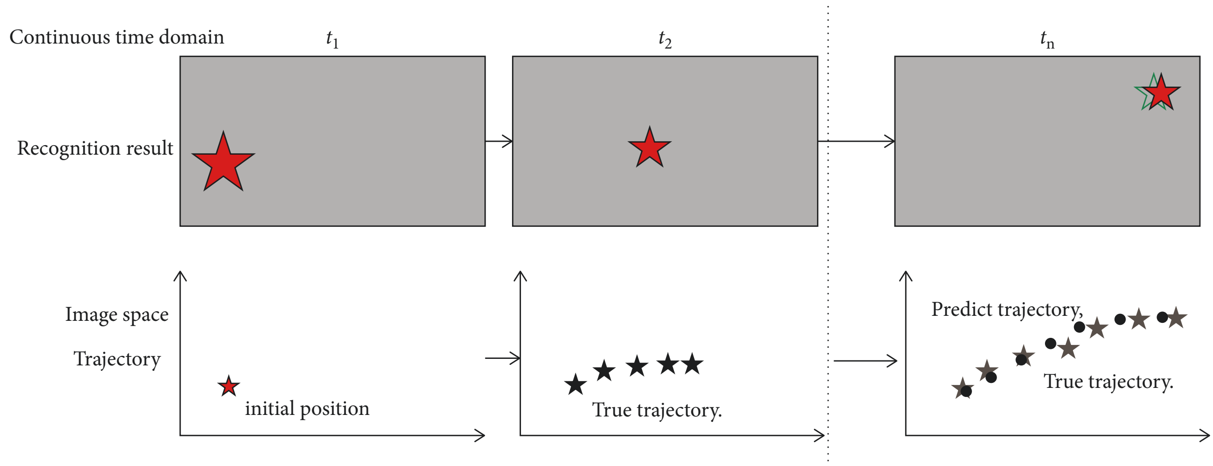

Figure 14: UAV image space history and time domain motion trajectory mapping method.

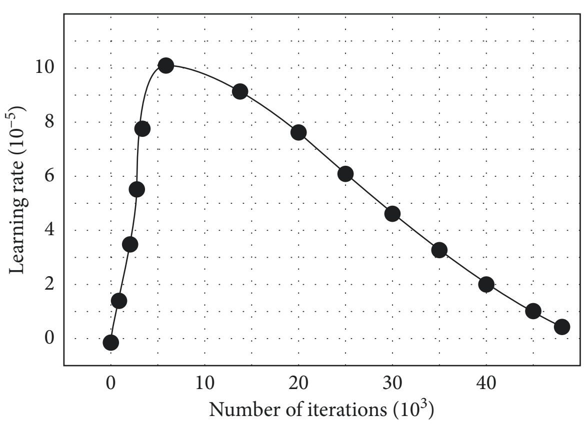

Figure 15: AUNN network learning rate curve.

Table 3: UAV data set structure.

Category	Number of pictures
Attack UAV	373
Payload/Command UAV	190
Scout UAV	197
Total	760

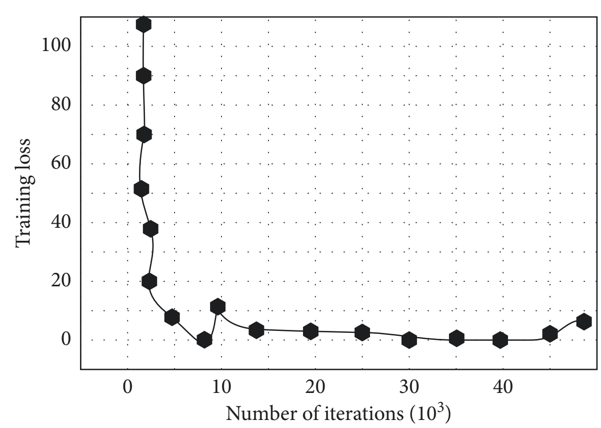

Figure 16: AUNN network loss curve.

3. Experimental Results and Analysis

The initial learning rate in the training phase is set to 0.001, and the learning rate is gradually increased in the first two generations. When the number of iterations is 380 times, the learning rate is reduced until the learning rate reaches 0.000001, which will not decrease, by which the loss function is further converged, and the learning rate curve is shown in Figure 15.

In order to verify the computing power of AUNN, an image data set for aerial UAV recognition was constructed based on the military and civilian fields. There are a total of 760 images in the data set, which are classified into reconnaissance, payload/control, and offensive targets according to the UAV's structure, functions, and executable tasks. The data components of each type of UAV are shown in Table 3.

The verification platform is DELLZ840, the CPU configuration of the central processing unit is Intel Xeon E5-2643 V3, the main frequency is 3. 4 GHz, the GPU is Quadro P5000, and the running memory is 32 GB, and the computing environment is Ubuntu 18.04. During the test, the IVFNN programming language was Python 3.7, with Tensorflow 2.0 and Opencv 3.2 as auxiliary high-level APIs.

After AUNN completes training, the total loss curve of the network is shown in Figure 16. After about 40,000 iterations, the final loss stabilizes at about 0. From the loss curve, it can be seen that the results of AUNN network training are relatively ideal.

AUNN's network training curve has a good convergence state, without gradient explosion, dispersion, disappearance, etc., which proves that the network designed by this research has a good feature learning ability. The average target recognition rate of AUNN is 82%, the average trajectory prediction rate is 80%, and the calculation speed is 24 frames/s. The network's UAV recognition and trajectory prediction effects are shown in Figure 17. Figures 17(a)~17(c) recognition effect of the 17 Figure network on command UAV, scout UAV, and attack UAV; Figures 17(d)~17(f)

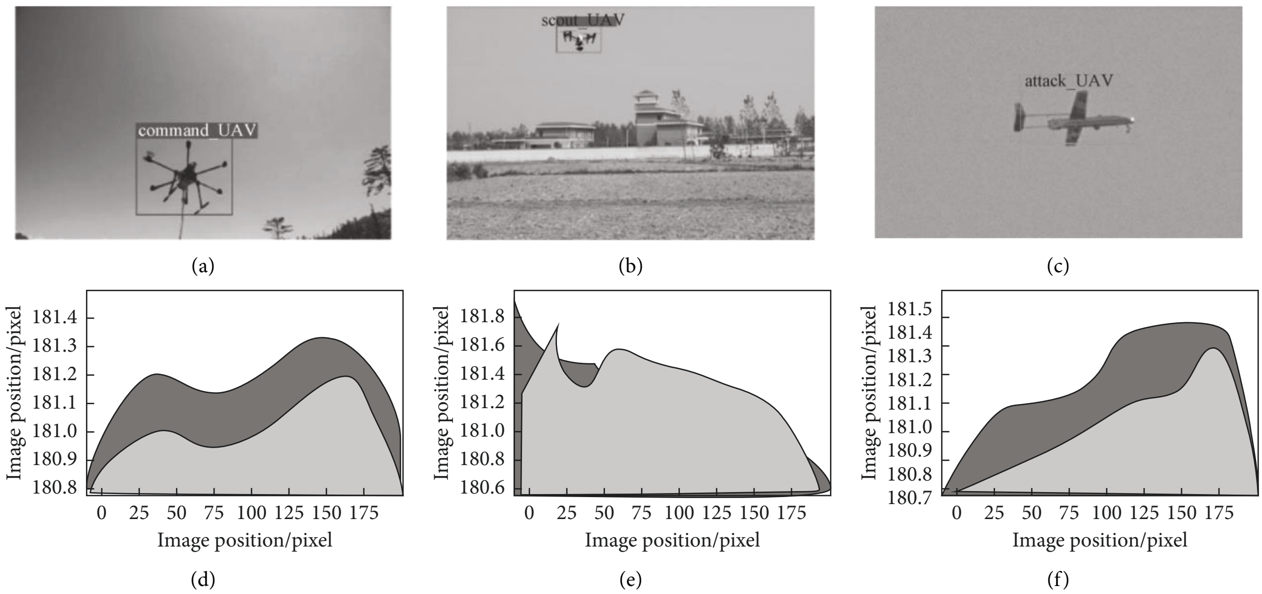

Figure 17: UAV recognition and trajectory prediction effect of AUNN network. (a) Recognition result of command UAV (b) Recognition result of scout UAV (c) Recognition result of attack UAV (d) Trajectory prediction result of command UAV (e) Trajectory prediction result of scout UAV (f) Trajectory prediction result of attack UAV.

correspond to the attacca trajectory prediction effect of 3 types of UAVs.

According to the results shown in Figure 17, AUNN can accurately identify and locate multitarget UAVs in the air under a ground-based platform. In the meantime, it can predict the UAV image space in the future time domain based on the current UAV image space trajectory to achieve rapid and accurate early warning for the “low, small, slow” UAV target, and provides machine vision support for the anti-UAV system.

4. Conclusion

The imbalance, turbidity, and instability of the high-performance computing early warning neural network in the use process are more important in the daily use process. The PSO algorithm in this paper can realize the optimization processing of the support vector regression model. While constructing the network high-performance computing early warning model, it uses three sets of different time granular data in the MAWI data set to carry out a detailed analysis with sample analysis. Finally, the experimental results show that the method proposed in this paper has better early warning performance for high-performance computing and can effectively solve the early warning problem of network high-performance computing. Finally, the flight state curve of the UAV is obtained through simulation, which verifies the effectiveness of the control law design. Therefore, this method can solve the flight control problem of UAV in complex situations.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

Line Loss Prediction of Distribution Network Based on BP Neural Network

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Distribution network line loss calculation refers to the calculation of the electrical energy loss, which is generated by all components in a distribution network system in a given period of time. Distribution network, as the end of the power network, is directly connected with users; there are many equipment on the network; the system has impedance, electric energy in the process of conversion, transmission and distribution with a lot of loss, so the calculation of distribution network line loss has very important economic significance. In addition, with the development of power network construction, the rationality of distribution network topology design and the comparison of practical effects of various measures need the guidance of line loss calculation. Line loss and line loss rate is one of the main criteria to reflect the operation of distribution system. Reducing line loss of distribution system is very important for the effective use of power and economic operation of distribution system. In order to better find the effective reduction method and lay the foundation for the scientific establishment of linear contraction targets. This study uses a line loss calculation method based on BP neural network. The method uses the super matching property of the network to map the complex nonlinear relationship between the line loss and the characteristic variables and stores the evolution of the line loss changes with the changes of the structural and operational variables of the distribution line. On the basis of analyzing the theoretical methods, management methods, and various loss reduction measures of power loss calculation, this study also analyzes the status quo and existing problems of line loss analysis and calculation and collects data from line loss calculation and theoretical line loss calculation methods. This study discusses in detail the method and idea of the application of the improved neural network in the estimation of distribution network line loss, and it is used to predict the line loss in a certain area, and the prediction result is good.

1. Introduction

Power generation and transmission systems transmit power to users through the distribution network, and the distribution network is directly connected to users at the end of the power network [1]. Due to the characteristics of low voltage grade, aging equipment, and long power supply radius of the distribution network, the line loss of the distribution network is more serious, accounting for more than 20% of the line loss of the power network at all voltage levels [2]. In recent years, as most countries in the world are in a state of insufficient energy, the contradiction between supply and demand and between the energy supply side and the energy purchase side is increasing [3], so how to prevent our country from falling into energy conflict has become a key domestic issue in recent years [4]. In the power system, line loss, as an important index to evaluate the efficiency and economy of power grid operation, has always been one of the important research and management contents of power grid companies [5]. Reasonable calculation and prediction of line loss rate is a method to effectively improve the management of power grid company, reduce power loss, and increase power grid income. Therefore, how to improve the accuracy of line loss rate prediction has very important practical significance. In recent years, many new methods for theoretical calculation of power distribution system line loss have emerged, and the calculation accuracy has been improved [6]. Add line loss calculation function and calculate line loss on time, to ensure that the system line loss can always be in the management of the management personnel. Design automatic line loss management system and improve load management device [7, 8]. The traditional manual management way already cannot adapt to the current management needs, the previous theoretical line loss is mostly artificial calculation, calculation workload is big, calculation cycle is long, and only a rough calculation for simple lines is impossible to calculate for complex circuit; limitation is very big; this requires us to use a computer for line loss calculation [9, 10]. It is very urgent to study the simple and effective computer aided distribution network line loss calculation method and implementation. This is also a more accurate calculation of the theoretical line loss and its distribution in the network and the institutionalization, standardization, and standardized line loss calculation work of the inevitable requirements.

2. Application of BP Neural Network Algorithm

2.1. Distribution Network Line Loss Calculation Scheme. Theoretically, the BP neural system can map all nonlinear relations and effectively deal with the nonlinear relations between characteristic variables and line losses [11]. For the selection of input variables and output variables of neural network, in a certain period of time, the line loss of distribution lines is related to many characteristic parameters, such as the active power supply of distribution lines, the reactive power supply, the capacity of distribution transformers, the length of distribution lines, the number of distribution transformers, and the total number of truncation of distribution lines [12]. Calculation scheme of line loss of distribution network using BP neural network is shown in Figure 1:

In this study, the relationship between the four characteristic parameters and line loss is analyzed. When applying neural network to modeling, the active power supply, reactive power supply, distribution capacity, and distribution line length are taken as the input of neural network, and the line output is taken as the output. Neural network structure is shown in Figure 2:

2.2. Raw Data Acquisition and Processing. The process of data sampling and sample selection is as follows.

2.2.1. Attribute Selection. During network modeling, it is necessary to input feature weights that can characterize the problem, which imposes certain requirements on the fault information on the shaping device. The number of attributes determines the success of network recognition to a large extent, so the choice of attribute number is directly related to the accuracy of calculation [13]. In addition, the selection of the number of attributes must take into account the difficulty of obtaining data, whether it is correct and perfect, and the selection of the number of attributes must consider various factors.

There are many characteristic variables that affect line loss in a distribution system. According to the above, there are many characteristic quantities that satisfy the above conditions, such as the total number of distribution lines, the number of distribution changes, the length of distribution lines, distribution capacity, and the distribution of the total reactive power and total active power of the distribution cabinet.

According to the strength of the correlation between the line loss and characteristic variables of the distribution system, this study chooses the total effective power of the line, the total response capacity of the line, the distribution voltage capacity, and the length of the distribution line as the input and output, that is, the line loss.

2.2.2. Data Collection. Select a portion of distribution system data in a specific area and sort the data by network code number. In order to match Matlab programming calculation, it is formatted into the matrix form. The data are divided into practice samples and test samples.

2.2.3. Data Processing. Before creating a network, make preparations. Since the data sizes of different samples are usually different, direct input without processing will affect convergence and processing speed. Therefore, data samples need to be standardized. Chemical processing can ensure that the data size is relatively close, avoid calculating some data with small sample size due to large size difference, and improve the accuracy of data processing [14]. The normalized calculation formula is as follows:

$$x_k = \frac{x_k - x_{\min}}{x_{\max} - x_{\min}}, \tag{1}$$

where $x_{\max}$ and represent the maximum and minimum input values in the input data.

2.3. Neural Network Building and Training. In the Matlab platform, the Matlab language is used for neural programming, and the data on the input samples have been standardized. The results after exercise were compared with actual data for easy comparison.

In the modeling and training process of the nervous system, training samples are represented by variable corpus, production samples are represented by t, and untrained samples are represented by the network created by Newff. After setting the corresponding parameters, it can continue [15]. About training, this study covers two main commands. The first is the network, which is used to define the coach's goals [16]. Teaching ends only when the error is below the target value. In general, the default root mean square error (MSE) is the main index to measure the validity of this error. The second is the network. During this period, this command is mainly used to set the maximum number of repetitions. When the number of repetitions exceeds the set limit, the exercise will automatically end.

As can be seen from the training results, the training process of the network was repeated for a total of 6 times, reaching the precision set by the training network. Therefore, the network training was stopped to prevent the network from falling into an overly suitable state. At this point, the mean exponential error and repetition rate of the

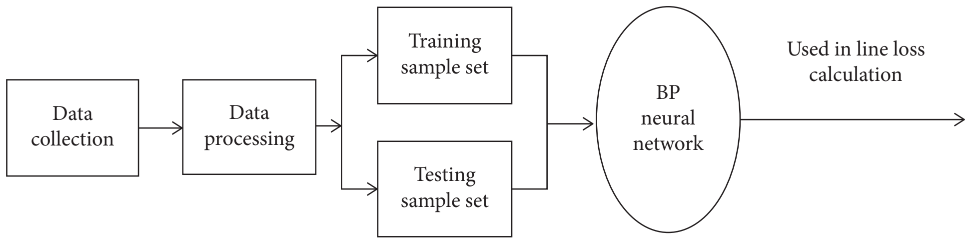

Figure 1: Calculation scheme of line loss of distribution network using BP neural network.

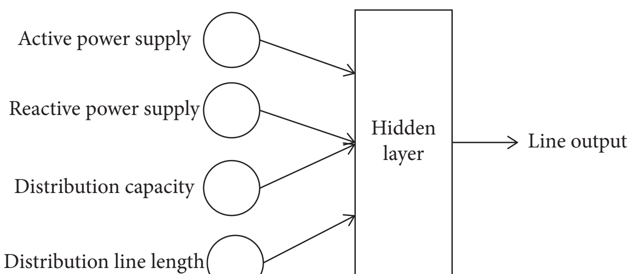

Figure 2: Neural network structure.

training samples were 0.00152 and 1.00E − 5, respectively, and the accuracy was already very high.

The larger the error target is, the more iterations need to be carried out, and the two are obviously positively correlated. Curve of mean square error and iteration times is shown in Figure 3:

Figure 4 shows that the mean square error of the training sample decreases with repetition, and the mean square error of the validation sample and test sample decreases correspondingly. However, the training performance of the nervous system is not higher with higher accuracy of training because the success rate of network generalization will be reduced, so it is necessary to avoid excessive online training.

Figure 5 is a linear regression analysis of the calculated loss frequency and the actual value obtained through the neural network model based on sample data. The deduction is the calculated line loss and the horizontal axis is the actual line loss. $R = [-1, 1]$ indicates the fitness level, and the higher the R value, the better the nervous system and computational performance. Neural network sample test results are shown in Figure 5:

Figure 5 is a sample of the nervous system. It can be seen that the calculated value of theoretical line loss in the figure is quite close to the actual value, and the error accuracy meets the requirements of actual calculation.

3. Line Loss Prediction Simulation of Distribution Network

3.1. Data Processing. In order to verify the feasibility of calculating the BP distribution line losses of the BP neural system studied in this study, simulation and empirical analysis were performed based on the daily load consumption of distribution users in a region within a region for 100 consecutive days. Distribution station area structure diagram is shown in Figure 6:

Based on the above analysis, for a specific location area, the change of energy consumption of each load node in the station area is the main reason for the change of energy loss value. Therefore, the daily response force of stress nodes is applied to the nervous system, and then, the loss rate of the line is obtained with the power. On this basis, combined with LM algorithm, the neural network model for calculating the line loss is obtained.

As for the sample data, they mainly contain 1 dependent variable and 16 independent variables. In short, the BP nervous system has 1 production node and 16 input nodes. The number of nodes is four, the hidden layer is one level, and the 16-4-1 network structure is defined, which is a network structure with 16 input nodes, 4 hidden level nodes, and one production node. In order to fully meet the training requirements of BP neural network, the data are processed to obtain independent variables, but there is no need to calculate the ratio of training variables.

3.2. Simulation Results. In six consecutive repetitions, the variance of the validation data did not decrease, but increased, exceeding the expected number of failures, so the online training ended automatically. At this point, the repetition estimation and root mean square error of training samples are very small, which are 1.08E − 7 and 7.05E − 8, respectively.

In the process of repeated online training, the average error of samples decreases gradually, and the average error of test samples and confirmation samples decreases gradually, but improving generalization ability is the main purpose of online training. The goodness of fit of the sample data is very close to 1, which achieves the expected requirements. Data simulation results are shown in Table 1:

In this study, the daily power consumption data of users in a certain distribution area for 100 consecutive days are used for network training, and the relationship between daily energy consumption and load node line loss ratio in the distribution station area is obtained, and then, the corresponding relationship is established on this basis. Table 1 shows that the absolute difference EA of all sample data is less than 1%, and the calculated results have good reliability. The relative difference is less than 5%, and the corresponding mean difference is 2.31814. Figure 7 shows a detailed fit of these test samples. Therefore, in the process of creating the online model, the representative of the sample should be

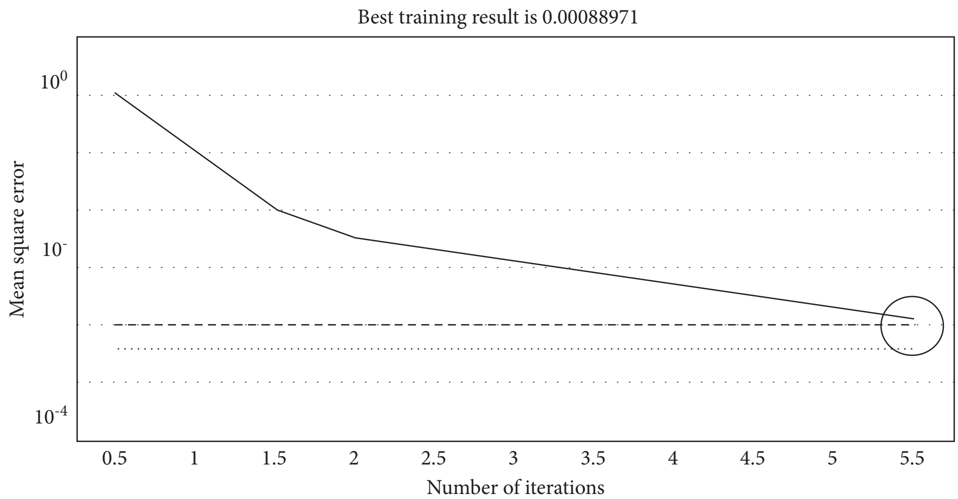

Figure 3: Curve of mean square error and iteration times.

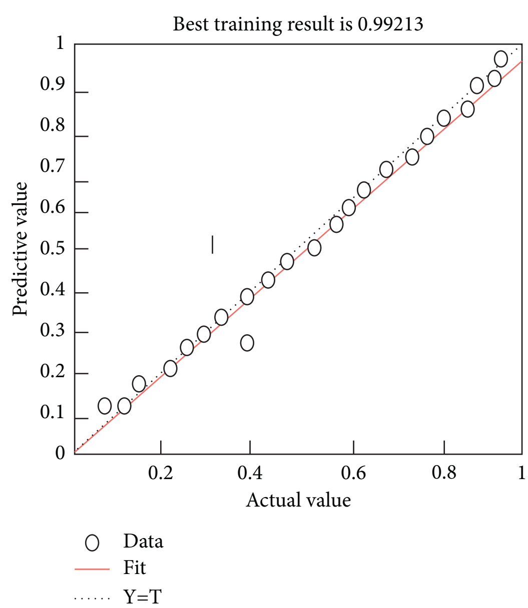

Figure 4: Sample data regression analysis.

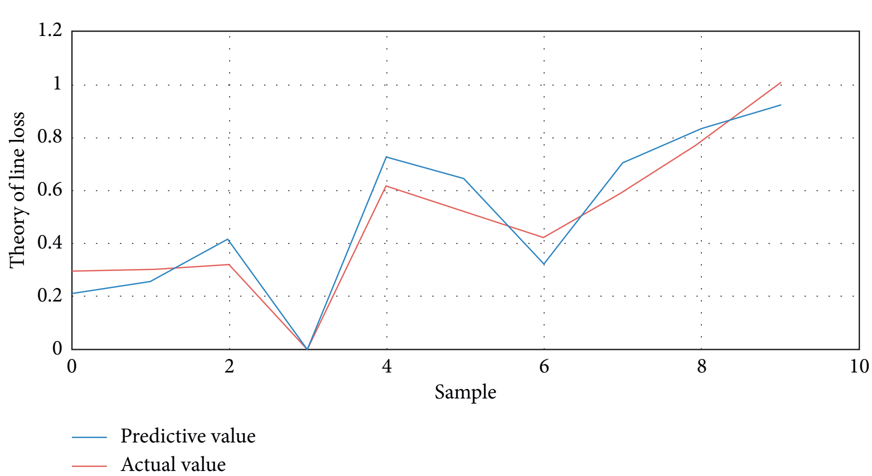

Figure 5: Neural network sample test results.

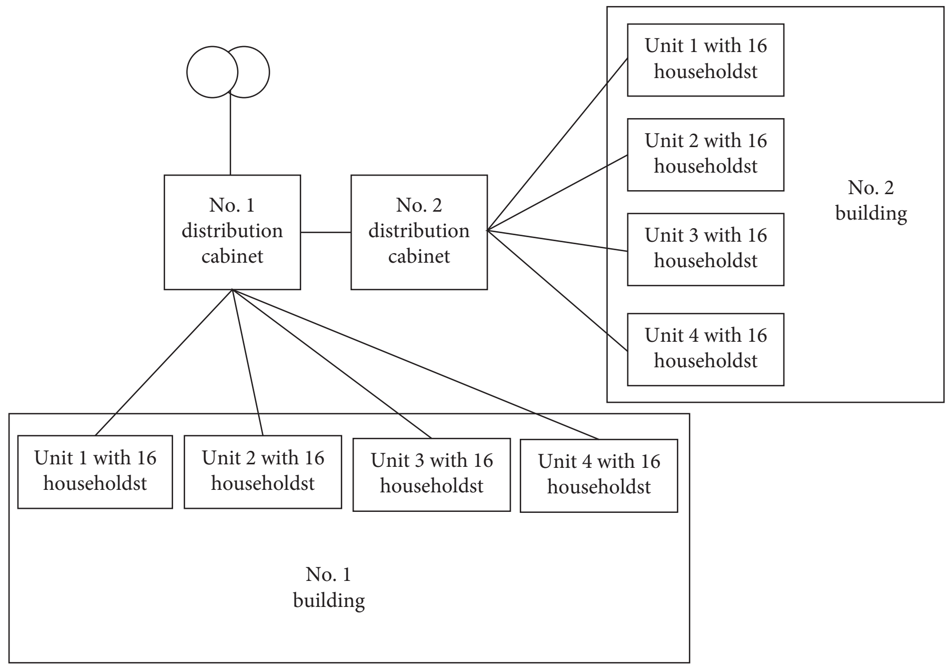

Figure 6: Distribution station area structure diagram.

Table 1: Data simulation results.

Line number	Calculate line loss rate (%)	Actual line loss rate (%)	Absolute error	Relative error
1	8.62	8.62	0	0
2	7.18	7.19	0.01%	0.71%
3	8.44	8.51	0.07%	3.02%
4	5.86	5.79	0.07%	3.11%
5	6.03	6.05	0.02%	9.24%
6	5.45	5.45	0	0
7	8.44	8.37	0.07%	4.14%
8	3.86	3.91	0.05%	0.52%
9	9.12	9.22	0.10%	0.67%
10	6.40	6.41	0.01%	0.53%

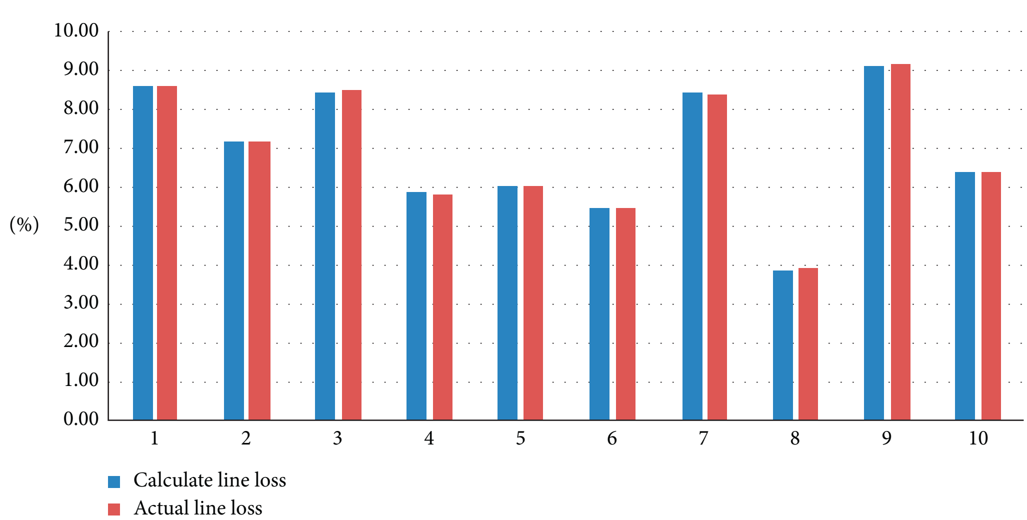

Figure 7: Comparison diagram of sample fitting degree.

considered when selecting the model, and its own structure should be considered to enrich the training sample as much as possible. Comparison diagram of sample fitting degree is shown in Figure 7.

4. Conclusion

Comprehensive and accurate theoretical calculation of line loss is very important. The clear composition of line loss and its distribution not only helps power supply companies to make plans and improve production and operating conditions but also plays an effective role in saving energy and reducing voltage [17, 18]. The lack of proper development plans over the years resulted in complex structures with many line segments and some lines with fine diameters, resulting in variables that did not meet the $R << x$ criteria for calculating energy flow. Based on this situation, some scholars use improved algorithms after research, such as the matching energy flow method, the improved repetition method, the before and after conclusion method, and the loop resistance method [19]. However, it is difficult to collect and satisfy the data required for these algorithms. The development of science and technology promotes the generation of several new algorithms which contribute to the development of distribution system [20]. The BP network model has a wide range of applications, and three-layer neural network is the main component of this type [21]. This model allows for very complex mappings that are linear to actions. The structure of the network is relatively simple, has high availability, and can perform arbitrary nonlinear adjustment of the input and output. These advantages make the BP nervous system quickly recognized by national scholars and widely used, such as imaging, data prediction, pattern analysis, and other fields [22]. Although BP algorithm has many advantages, it inevitably has disadvantages such as slow Internet speed, easy network oscillation, and easy to fall to the lowest point of the network. Scientists in China are determined to correct the inherent defects of BP algorithm and have achieved remarkable results. Xin et al. [23] used a model-based BP neural network algorithm to change the speed of the Internet. Jiang et al. [24] used an improved algorithm that uses the concept of simulated light lines to configure online speed learning. Using this improved algorithm can significantly improve network speed. Wang et al. [25] suggested that each weight should be relative to the initial learning rate. As the network adapts strongly, the learning rate corresponding to each weight has changed to achieve optimal results. The BP network model has many advantages. Now, more and more scholars have begun to study its application in line loss calculation of distribution system and have made some achievements. This is also a new development strategy of the artificial neural network model and opens up a new theoretical method for calculating the line loss of distribution system. However, overall, the current level is still exploratory. Due to the lack of general network design methods, neural networks are limited by practical use because they rely on experimental methods used in practice [26].

Therefore, this study focuses on the calculation of line loss and concrete practical calculation examples. In this study, a BP neural network model is used to calculate the line loss of the distribution system. The results show that using BP network to calculate the line loss of distribution system has the characteristics of the simple network model, fast training speed and high precision. Simulation results show that this method has great advantages in training time and calculation accuracy. It can simulate the optimal BP network type for the line loss calculation of the distribution system in a short time and has high calculation accuracy. In order to meet the needs of line loss management and analysis of distribution network, this study discusses a theoretical line loss prediction and analysis method using neural network and uses relevant algorithms and models. The prediction results also show that this arrangement of input samples may contain the main factors affecting row loss.

The biggest problem of this study is that neural network has a high requirement for data. However, from the current situation, the requirement of providing a large number of real data obviously does not meet the objective conditions, which is also the main direction of future scholars.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Modeling the Susceptibility of Forest Fires Using a Genetic Algorithm: A Case Study in Mountain Areas of Southwestern China

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Modeling fire susceptibility in fire-prone areas of forest ecosystems was essential for providing guidance to implement prevention and control measures of forest fires. Traditional models were developed on the basis of random selection of absence data (i.e., nonfire data from unburned areas), which could bring uncertainties to modeling results. Here, a new model with the genetic algorithm for Rule-set Production (GARP) algorithm and 10 environmental layers was proposed to process presence-only data in the susceptibility modeling of forest fires in Chongqing city. To do this, 70% of 684 fire occurrence data (479) during the period of 2000–2018 were applied to train the proposed model. And, 30% of these fire occurrence data (205) and the same amount of no-fire data (205) were emerged as validation dataset. The results showed that, for some environmental layers (i.e., distance to the nearest road, land cover, precipitation, distance to the nearest settlement, aspect, relative humidity, elevation, wind speed, and temperature), their *P* values were less than 0.05, indicating that these 9 environmental layers have significant influence on the spatial distribution of fire susceptibility in Chongqing city. On the contrary, with a higher *P* value (i.e., 0.126), the slope layer has an insignificant effect on fire susceptibility in the study area. Furthermore, the results of receiver operating characteristic analysis (ROC) showed that the proposed model has a good performance with an AUC value of 0.869, an accuracy value of 0.732, a sensitivity value of 0.59, a specificity value of 0.873, a positive predictive value of 0.823, and a negative predictive value of 0.681. This study revealed the validity of the proposed model in modeling the susceptibility of forest fires.

1. Introduction

With intensive global warming and increasing urbanization, forest fires around the world occurred frequently in recent years, resulting in severe impacts on the safety of forest ecosystems [1, 2]. The geographical distribution of fire susceptibility was an urgent need to implement adequate management actions [3–6]. It was of importance to perform studies on modeling the susceptibility of forest fires [7, 8].

Meteorological factors (e.g., relative humidity, wind speed, air temperature, and precipitation) were thought to be important contributors to fire occurrence, which have already been adopted to forecast the fire risk in operational systems [9–12]. However, the occurrence of forest fires was also result of other environmental factors (e.g., land cover, topography, and human activity) [13, 14]. Thus, comprehensive models involving multiple factors were emerging in the development of modeling fire susceptibility [15, 16].

The similar development is also seen in the field of landslide susceptibility mapping [17]. Some studies reported that machine learning algorithms (e.g., random forest [18, 19], support vector machine [18], boosted regression tree [18], naïve Bayes classifier [20], and extreme gradient boosting [19, 20]) could be used for building comprehensive models.

Therefore, recent advances have mainly focused on utilizing machine learning algorithms to develop comprehensive models in fire susceptibility modeling. For instance, to map the fire susceptibility in Iran, Pourtaghi, literature [21] proposed Shannon's entropy and frequency ratio models for combining several environmental factors (i.e., topography data, soil texture, proximity data, normalized difference vegetation index, land use map, and meteorological data). Following that, literature [22] applied boosted regression tree, generalized additive model, and random forest to investigate the importance of 15 condition factors on forest fire and model fire susceptibility. Taking 10 ignition factors into consideration, literature [23] developed a fire susceptibility model using the neural fuzzy inference system at a tropical area. Thereafter, literature [15] established an evolutionary optimized gradient boosted decision tree model by incorporating 18 ignition factors of forest fires. In 2019, literature [24] utilized 10 related conditioning factors and occurrences data of previous fires to train the LogitBoost ensemble-based decision tree machine learning method for mapping the fire susceptibility at the Lao Cai region of Vietnam. Based on historical fire data and 8 risk factors, literature [16] proposed a new operational model with the ant-miner algorithm to predict the risk of forest fires in cloud-rich areas of southwestern China. More recently, involving 12 influencing factors, literature [25] employed a weighted approach to integrate the forest fire susceptibility outputs of different machine learning techniques in a forest-agriculture mosaic landscape of southern India.

Since the above models could not handle the presence-only data directly, a certain number of absence data (i.e., no-fire data from unburned areas) were generally required. However, areas lacking records of fire occurrence might not truly represent areas of fire absence [26, 27]. Therefore, the selection of no-fire data would bring uncertainties to modeling results. Recently, it was reported that genetic algorithm for rule-set production (GARP) could be a robust model, which could effectively deal with presence-only data [28–30]. Here, we made the attempt to apply GARP to propose a new model for modeling fire susceptibility.

Thus, the main objective is to propose a genetic algorithm-based model, which could process the presence-only data for mapping the susceptibility of forest fire. Furthermore, the susceptibility of forest fire in a mountain area of southwestern China was mapped and then was evaluated using a receiver operating characteristic analysis. Additionally, we try to investigate which environmental layers have significant influence on the susceptibility of forest fires in the study area. As a new attempt to process the presence-only fire occurrence data, the proposed model has the potential of being applied in other southwest regions of China and could provide guidance for the implementation of forest fire prevention and control measures.

2. Study Area

With an area of around 82,402 km^2, Chongqing city was selected in this research as the study area (see Figure 1). It was located in southwestern China, which was bounded by 105° 03′ to 110° 02′ E longitudes and 28°02′ to 32° 03′ N latitudes. This area was mainly comprised of high mountains and deep valleys with an altitude ranging from 73 to 2,797 m. It possesses a continental humid subtropical monsoon climate with an average relative humidity of 71–81%, an annual rainfall of 1,000–1,350 mm, and an annual average temperature of 16–18°C. The evergreen broad-leaved forest was the dominant vegetation type in the study area.

Due to its topographic, geological, and climate features, Chongqing city has experienced a more frequent occurrence of forest fires. This region was a typical area for carrying out studies on modeling the susceptibility of forest fires in mountain areas of southwestern China.

3. Materials and Methods

3.1. Input Fire Occurrence Data. With authorization access, fire occurrence data during the period 2000–2018 were applied for further studies. Locations of these fires were sourced from an operational monitoring system that was based on MODIS images and field surveys. Fire occurrence data includes attributes of latitude, longitude, and ignition time, which were accessed from Forest Fire Control Office of Chongqing and Forest Fire Protection Network of China in Chongqing city. In total, the number of fire occurrence data was 684.

Out of 684 fire data, 479 (70%) were randomly selected as the training sample and the remaining 205 (30%) were kept for validation purpose. Since GARP belongs to presence-only approach, which does not need the existence of no-fire data in training phase, only the same amount of no-fire data (205) were randomly sampled for model validation [31]. Finally, the total number of data used in this study was 889 (i.e., training sample: 479 and validation sample: 410), which is plotted in Figure 1.

3.2. Environmental Layers. Four groups of environmental layers influencing fire occurrence (i.e., annual weather, land cover, topographic, and human activity data) were used in the GARP approach (see in Table 1).

Daily weather data at 12 national stations across the study area were obtained first from the National Meteorological Network of China (https://data.cma.cn). Annual weather data (i.e., relative humidity, wind speed, temperature, and precipitation) were then calculated using daily weather observations during 2000–2018. Finally, annual weather data were interpolated to a grid of 1 km spatial resolution using the inverse distance weight method. Interpolations of annual relative humidity, annual wind speed, annual temperature, and annual precipitation were regarded as environmental layers in the following GARP approach.

Land cover was a crucial factor for fire occurrence, since it could provide specific information on the type and distribution of vegetation. Land cover data used in this study were obtained from the Resource and Environment Data Cloud Platform (https://www.resdc.cn/). These data have 1-km spatial resolution, which was an updated version of 2015 land cover data based on Landsat 8 remote sensing images in 2018. Land cover was regarded as one of the other environmental layers in the following GARP approach, which is illustrated in Figure 2(e).

Topography layers were considered other causes of forest fires. In this research, 20 digital elevation model images (ASTGTM2) with a spatial resolution of 30 m were downloaded from the Geospatial Data Cloud website (https://www.gscloud.cn/). To extract the elevation layer, ASTGTM2 data was were preprocessed using image mosaic and clipping operations in spatial analyst tools of ArcGIS software (version 10.2). Moreover, for matching the spatial resolution

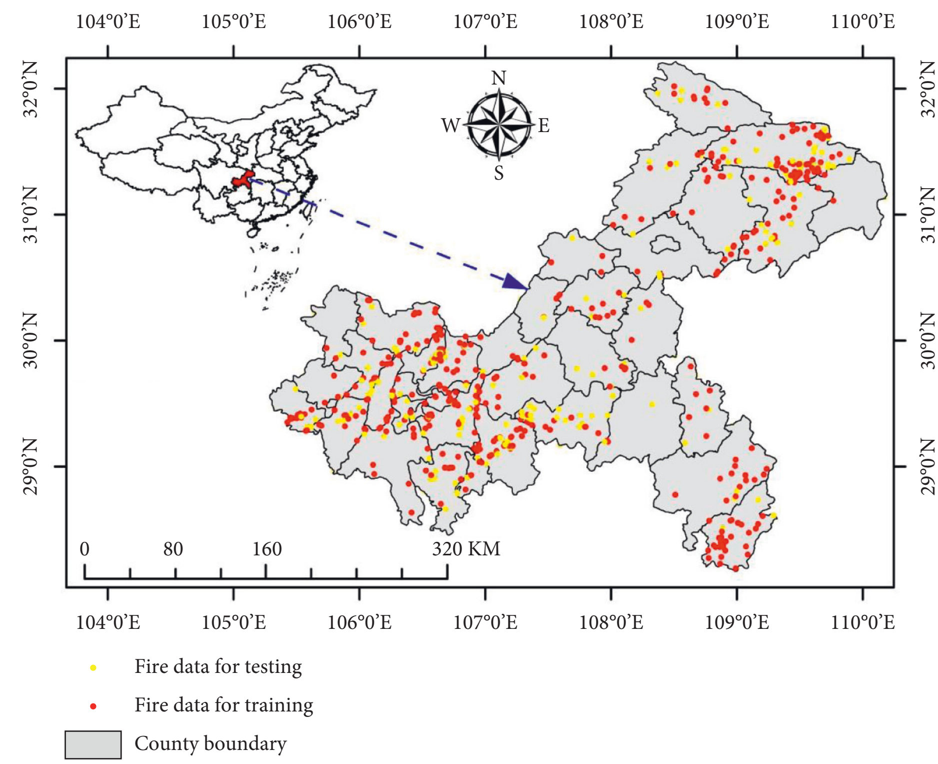

Figure 1: Locations of the study area and fire data.

Table 1: The details of data used in this study.

Category	Data	Type	Resolution/ scale	Source
Fire	Ignition	—	—	The Forest Fire Control Office of Chongqing and Forest Fire Protection Network of China
Annual weather	Relative humidity	Continuous	—	The National Meteorological Network of China (https://data.cma.cn)
	Wind speed	Continuous	—	
	Temperature	Continuous	—	
	Precipitation	Continuous	—	
Land cover	Land cover type	Discrete	30 m	The Resource and Environment Data Cloud Platform (https://www.resdc.cn/)
Topography	Elevation	Continuous	30 m	Geospatial data cloud website (https://www.gscloud.cn/)
	Aspect	Discrete	30 m	
	Slope	Continuous	30 m	
Human activity	Distance to the nearest road	Discrete	200 m	Baidu map (https://www.lbsyun.baidu.com/index.php)
	Distance to the nearest settlement	Discrete	1 km	

of other environmental layers, the bilinear interpolation was applied to resample the spatial resolution of elevation data (30 m) to 1 km. Based on resampled data, "Surface" tool of ArcGIS software was then employed to extract the other two topography layers (i.e., aspect and slope).

In addition, two other environmental layers (i.e., distance to the nearest settlement and distance to the nearest road) were used to assess the influence of human activity on fire occurrence. Based on settlement distribution and road network data in Chongqing city, we calculated the distance to the nearest settlement and the distance to the nearest road using a buffer analysis tool of ArcGIS software. These calculated layers were then discretized into equal intervals (i.e., distance to the nearest settlement: 0-1 km, 1-2 km, 2-3 km, 3-4 km, and >4 km and distance to the nearest road: 0–200 m, 200–400 m, 400–600 m, 600–800 m, and >800 m), according to our previous experience in this area [16].

3.3. Developing GARP Model. Through DesktopGARP program (version 1.1.6), a genetic algorithm for rule-set prediction (GARP) was performed in this study to model fire susceptibility (see in Figure 3). As an expert system and machine learning algorithm, this algorithm could develop a set of rules to relate fire occurrence data to environmental layers. These rules then could be projected

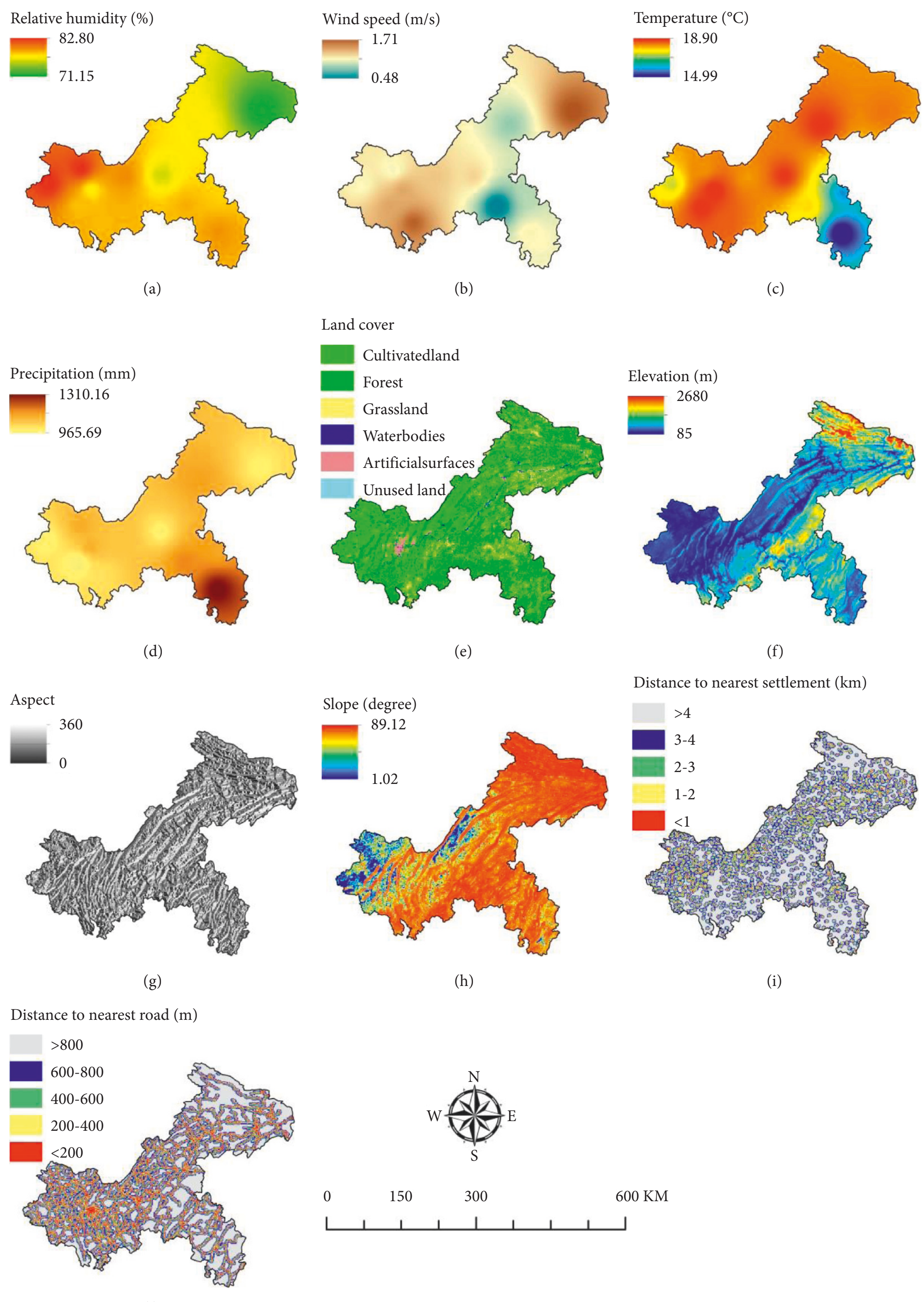

Figure 2: Environmental layers influenced the occurrence of forest fires: (a) relative humidity, (b) wind speed, (c) temperature, (d) precipitation, (e) land cover, (f) elevation, (g) aspect, (h) slope, (i) distance to the nearest settlement, and (j) distance to the nearest road.

onto a landscape and applied to model the fire susceptibility [32].

Before developing the GARP model, a jackknifing procedure was carried out to determine which environmental layers were more significant. This process was accomplished using an "environmental layers panel" in DesktopGARP, which could generate a set of tasks with various combinations of environmental layers. After running these tasks, a multiple linear regression was run to understand which environmental layers have a significant impact on resulting errors (https://www.nhm.ku.edu/desktopgarp/PrinterUM.html). Based on the analysis

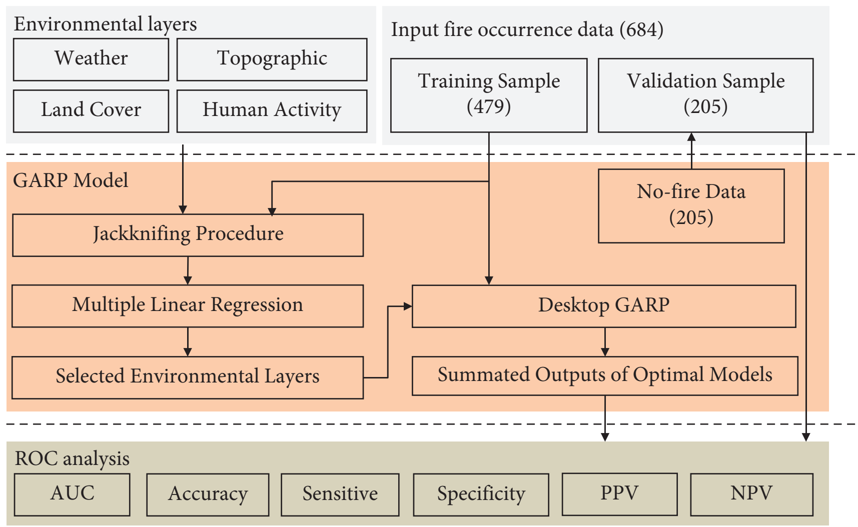

Figure 3: The flowchart of the proposed model: (a) data and processing, (b) model developing, and (c) model evaluating.

results, significant environmental layers were designated for subsequent experiments.

To optimize the parameters of the GARP approach, 200 models with max 1,000 iterations and a convergence limit of 0.01 were established in DesktopGARP (see Table 2). During the process of model building, the training sample (i.e., 479 data mentioned above) was internally divided into a 70%/30%. Then, 20 best models under 10% hard omission threshold and 50% commission threshold were selected using a subset approach in DesktopGARP. Finally, based on commission errors of these 20 subset models, output maps of 10 optimal models were imported into ArcMap software and summated using a raster calculator tool of spatial analyst extension. In the summated map, a higher pixel value means a greater potential of forest fires.

3.4. Evaluating Model's Performance. Based on the validation sample (i.e., 410 data mentioned above), the performance of the proposed model was evaluated using a receiver operating characteristic analysis (ROC). Area under curve (AUC) was measured and additional metrics could be calculated using the following formulas[24, 33]:

$$\begin{aligned} \text{accuracy} &= \frac{(TP+TN)}{(TP+FP+FN+TN)}, \\ \text{sensitivity} &= \frac{TP}{(TP+FN)}, \\ \text{specificity} &= \frac{TN}{(TN+FP)}, \\ \text{positive predictive value} &= \frac{TP}{(TP+FP)}, \\ \text{negative predictive value} &= \frac{TN}{(TN+FN)}, \end{aligned} \tag{1}$$

where TP is the true positive, FP is the false positive, FN is the false negative, and TN is the true negative

4. Results

4.1. Significant Layers Influencing Fire Susceptibility. Initially, 10 environmental layers influencing fire occurrence were selected to develop the GARP algorithm. However, to improve the effectiveness of proposed model, multiple linear regression analysis results in the removal of one environmental layer (i.e., slope). Specifically, the impact of environmental layers could be identified by P values in the multiple linear regression analysis. A smaller P value means a more significance of the environmental layer in modeling the fire susceptibility [34].

The results in Table 3 showed that P values of these layers respectively are as follows: distance to the nearest road ($P < 0.001$), land cover ($P < 0.001$), precipitation ($P < 0.001$), distance to the nearest settlement ($P < 0.001$), aspect ($P < 0.001$), relative humidity ($P < 0.001$), elevation ($P = 0.004$), wind speed ($P = 0.005$), and temperature ($P = 0.014$). All P values of these environmental layers were less than 0.05, indicating that the susceptibility of forest fires in Chongqing city was significantly influenced by human activities, land cover, and weather factors.

However, Table 3 further shows that the slope layer has a higher P value (i.e., $0.126 > 0.05$). This means that slope has an insignificant impact on the susceptibility of forest fires in Chongqing city. As a result, the susceptibility of forest fires was mapped using 9 environmental layers (i.e., distance to the nearest road, land cover, precipitation, distance to the nearest settlement, aspect, relative humidity, elevation, wind speed, and temperature), followed by performance evaluation.

4.2. Susceptibility Map of Forest Fires. After running the subset approach in DesktopGARP, 10 optimal models were developed and summated using ArcMap software. After that, a composite map was generated to illustrate the spatial

Table 2: Parameters setting in DesktopGARP.

Optimization parameters		Best subset selection parameters	
Runs	200	Omission measure type	Extrinsic-hard
Convergence limit	0.01	Omission threshold	10
Maximum iterations	1000	Commission threshold	50
Rule types	Atomic Range Negated range logistic regression	Total models under hard omission threshold	20

Table 3: Environmental layers influencing the susceptibility of forest fires.

Environmental layers	Coefficients	Standard deviation	t Stat	P value	Effect	Included or excluded
(Intercept)	44.165	0.452	97.634	$P < 0.001$	Significant	Included
Distance to the nearest road	−12.176	0.271	−44.856	$P < 0.001$	Significant	Included
Land cover	−9.574	0.271	−35.270	$P < 0.001$	Significant	Included
Precipitation	−3.104	0.271	−11.434	$P < 0.001$	Significant	Included
Distance to the nearest settlement	−2.987	0.271	−11.004	$P < 0.001$	Significant	Included
Aspect	−2.100	0.271	−7.738	$P < 0.001$	Significant	Included
Relative humidity	−1.497	0.271	−5.513	$P < 0.001$	Significant	Included
Elevation	0.781	0.271	2.877	0.004	Significant	Included
Wind speed	0.760	0.271	2.801	0.005	Significant	Included
Temperature	0.664	0.271	2.446	0.014	Significant	Included
Slope	−0.415	0.271	−1.530	0.126	Insignificant	Excluded

Note: environmental layers are ranked by P value.

distribution of fire susceptibility, in which a higher pixel value means greater model agreements and a higher fire risk level. Finally, the fire susceptibility map was categorized into 6 classes: very low, low, moderate, high, very high, and extremely high risks.

From Figure 4, it can be seen that high risk of forest fires (i.e., model agreements were higher than 8) primarily distributed in southwestern, central, and northeastern parts of the study area. This distribution was similar to that of human activity factors (i.e., distance to the nearest road in Figure 2(i) and distance to the nearest settlement in Figure 2(j)), which verifies a fact in Table 2 that distance to the nearest road and distance to the nearest settlement were more significant layers influencing the fire susceptibility.

On the contrary, Figure 4 displays that the risk of forest fires was low in the southeastern region of Chongqing city, where human activity was high and vegetation was rich. It is evident that a higher precipitation in this region (see Figure 2(d)) resulted in a changing distribution of forest fires. Also, the results in Table 2 verified that the precipitation layer was an important layer influencing the fire occurrence.

For the susceptibility map of forest fires (Figure 4), the area and percentage associated with each risk level can be found in Table 4. Specifically, 11.44% and 8.44% out of the whole study area were located in extremely high and very high fire susceptible areas. Moreover, 9.36% and 6.74% were located in high and moderate fire susceptible areas, respectively. Furthermore, 4.39% and 59.64% were located in very low and low fire susceptible areas, respectively.

4.3. Model Performance. As an effective technique to measure model's performance [18], a ROC analysis was applied in this study to evaluate the performance of the proposed model. In particular, based on the validation dataset mentioned above, the ROC curve was illustrated by plotting the false-positive fraction of the proposed model on x-axis and true-positive fraction of the proposed model on the y-axis. If the proposed model has no effect on fire susceptibility modeling, the ROC curve is close to the upper left corner (i.e., 1 : 1 line) and its AUC value will be 0.5 [11]. A value between 0.85 and 0.95 means a good performance of the proposed model [31].

The results in Figure 5 showed that the AUC value was 0.869, which indicates that the GARP model has a good performance. Moreover, Figure 5 demonstrates other 5 metrics to measure model's performance, that is, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value, separately. Figure 5 shows that accuracy was 0.732, sensitivity was 0.59, specificity was 0.873, PPV was 0.823, and NPV was 0.681. These additional quantitative metrics further suggested the validity of the proposed model.

5. Discussion

5.1. Result Analysis. Unlike traditional models [16, 21, 22, 24], the proposed model does not require the input of no-fire data. This means that additional uncertainties caused by the selection of no-fire data would not affect the modeling results, since forest areas lacking records of fire occurrence might not truly represent areas of fire absence [26, 27]. Our obtained results also further verified that the proposed model has a good performance with an AUC value of 0.869 and accuracy value of 0.732, which were close to results of our previous studies in this area (i.e., accuracy values were from 0.58 to 0.79) [16].

However, for the proposed model, modeling tasks in this research might be more challenging. Specifically, due to

Table 4: Area and percentage of each risk level in the susceptibility map of forest fires.

Class	Area (km^2)	Percentage
Very low risk	46511	59.64
Low risk	3420	4.39
Moderate risk	5255	6.74
High risk	7300	9.36
Very high risk	6579	8.44
Extremely high risk	8920	11.44

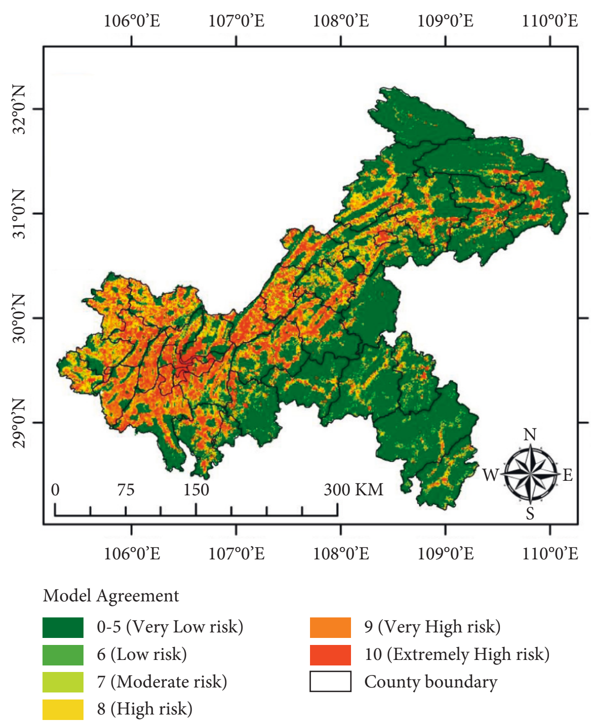

Figure 4: Susceptibility map of forest fires using the proposed model.

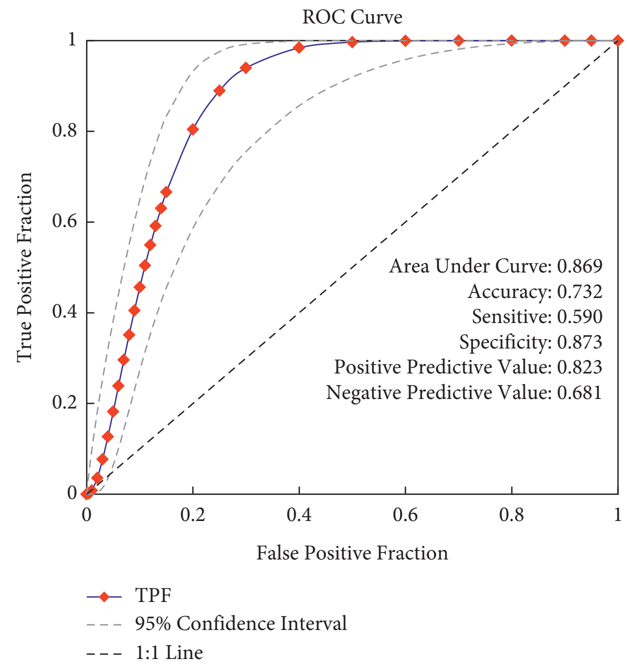

Figure 5: Performance evaluation of the proposed model using ROC analysis.

input limitations of DesktopGARP, annual weather data were applied as model inputs. Compared to daily weather data used in [16], the annual weather data might not be accurate indicators of weather conditions on the day of fire occurrence. Therefore, if daily weather data were applied in future studies, there was a further space for improving the accuracy of proposed model.

Compared to maximum entropy models (i.e., a different presence-only model [35]), the proposed model in this study has a higher accuracy. In particular, the maximum entropy models (Maxent) have been utilized to develop a new daily fire danger index [36], to predict the possibility of lightning-caused fire occurrence [37] and to examine the spatial distribution and temporal variation in forest fire occurrence [38]. Accuracies of these studies in terms of AUC value were 0.752 to 0.852 [36], 0.866 [37], and 0.816 to 0.847 [38]. These reported studies further verified the validity of the GARP model in modeling the susceptibility of forest fires.

Moreover, the results in Table 2 showed that the slope layer has an insignificant influence on fire occurrence in this research, even though slope could affect the fire spread rate [21, 24]. This is consistent with findings by Dlamini [26]. The main reason might be that the topography of Chongqing city (i.e., a famous mountain city in China) was dominated by high mountains and deep valleys (see Figure 2(h)). Figure 1 exhibits that fire occurrence data were primarily distributed in mountainous areas with steeper slopes. With low variations at these fire data locations [26], slope factor would have an insignificant effect on the modeling results.

Findings in Figure 2, Figure 4, and Table 2 indicated that human activities significantly influence the susceptibility of forest fires. The spatial distributions of high risks were similar to spatial distributions of distance to the nearest road in Figure 2(i) and distance to the nearest settlement in Figure 2(j). In a mountain city like Chongqing city, road network and settlement distribution mean an easy accessibility of facilities and services [39]. Therefore, these two factors could effectively reflect the intensity of human activities, which could significantly impact on fire occurrence.

Similar to the results in some reported studies [5, 16, 23], findings in Figure 4 and Table 2 indicated that land cover and weather factors greatly affect the fire susceptibility. The primary cause of this was that land cover and weather factors have great influences on fuel moisture and loading [26].

5.2. Improvement Strategy. Based on DesktopGARP program, a new model using the genetic algorithm was proposed in this study to model the susceptibility of forest fires. As a new attempt to process presence-only fire occurrence data, the proposed model would not bring uncertainties to the modeling results. And, our findings suggested that the proposed model has a good performance in modeling the susceptibility of forest fires. However, these findings should be interpreted guardedly.

The proposed method achieved better results in a mountain area of southwestern China. To further verify its validity, more studies need to be carried out in a wider range of forest ecosystems. Meanwhile, beyond environmental layers used in this study (i.e., annual weather, land cover, topographic, and human activity factors), more factors influencing the occurrence of forest fires should be considered in the building of the susceptibility model in future research.

Moreover, accurate weather data were critical to improve the model's performance [16]. In this study, due to input limitations of the DesktopGARP algorithm, the proposed model was only able to handle annual weather data. This would hinder the performance of the proposed model. Therefore, more efforts need to be devoted to future research to improve the performance of the proposed model in handling daily weather data.

Furthermore, the presence-only model showed a great advantage when absence data of species were unavailable [31, 32]. It has been successfully applied in spatial modeling of disease [28, 40, 41], habitat predicting of species distribution [42–44], and hazard mapping of natural disasters [45–47]. Since wildfires have similar conceptual and mathematical rules with plants or animals, ecological niche modeling would be an inductive approach to compute wildfires ignition and spreading likelihood [48]. Therefore, in future studies, more ecological niche modeling could be further considered for modeling the fire susceptibility.

6. Conclusions

As a very destructive natural hazard, forest fire frequently occurred in mountain areas of southwestern China. Numerous models were proposed to model the fire susceptibility, which could facilitate the implementation of effective prevention and control measures. However, since a certain amount of absence data are required to train traditional models, uncertainties could be introduced into modeling results. Thus, a new model using GARP approach was utilized to process presence-only data in modeling the susceptibility of forest fires in Chongqing city. Initially, 479 fire occurrence data were applied to train the proposed model with 10 environmental layers. In addition, 205 fire occurrence data and 205 no-fire data were used as the validation dataset. Based on them, the proposed model was evaluated using a receiver operating characteristic analysis with metrics of AUC, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value. The results showed that distance to the nearest road, land cover, precipitation, distance to the nearest settlement, aspect, relative humidity, elevation, wind speed, and temperature layers have significantly influence on the spatial distribution of fire susceptibility in Chongqing city. Conversely, the slope layer has an insignificant effect on modeling results, since its P value was more than 0.05. Furthermore, the ROC results showed that AUC was 0.869, accuracy was 0.732, sensitivity was 0.59, specificity was 0.873, positive predictive value was 0.823, and negative predictive value was 0.681. These metrics revealed that the proposed model has good performance. To further verify model's validity, more studies need to be carried out in a wider range of forest ecosystems. Moreover, the performance of the proposed model could be improved by using accurate weather data in future research.

Data Availability

Data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

Acknowledgments

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Research Article

Depression Identification of Students Based on Campus Social Platform Data and Deep Learning

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Depression is one of the most common psychological problems faced by human society. Because of less social experience, low psychological endurance, and the multiple responsibilities of future families and society, college students have become one of the most vulnerable groups to suffer from depression. This paper explores an automatic identification method to identify patients with early depression tendency through deep mining of online information of campus social platform users. First, we comprehensively analyze the common characteristics of emotion and behavior on the campus social platform for depression. Secondly, the experimental corpus is formed by preprocessing operations such as deprivation, word segmentation, and denoising of the original data. Finally, the depression recognition is transformed into a text classification problem, and a shallow support vector machine and a deep convolutional neural network model are, respectively, constructed based on the experimental corpus. Combined with the features of depression blog, the algorithm was further improved, and a dual-input convolutional neural network algorithm compatible with multiple features was proposed. The experiments showed that the recognition rate was effectively improved.

1. Introduction

Depression is one of the most common psychological problems faced by human society. The harm and impact of depression are very serious. Suicide rates among people with depression are very high, with 3,000 people with depression committing suicide every day worldwide [1]. Considering the personal suffering of depression patients, the impact on relatives and friends, and the resources spent on treatment, it can be said that depression has become a heavy burden on human society. In college students, a special group with less social experience and low psychological endurance, but also bearing multiple responsibilities of future family and society, the incidence of depression is significantly higher than that of the general population.

In order to fight against depression, people have done a lot of research on its causes, diagnosis, and treatment and put forward diagnostic methods based on psychology and physiology, such as various scales. Traditional diagnostic methods mainly obtain basic information about people's psychological and physiological states through verbal communication, questionnaires, physical examinations, etc. From this information, the basis for diagnosis is obtained. In the process of diagnosis, the acquisition, processing, and analysis of information consume a lot of time, money, and material. The traditional method also faces a problem: very low medical treatment rate. Due to the lack of understanding of psychological problems, many people do not realize that they are suffering from depression and do not know whether to seek help when they have problems with their physical and mental health. Some people have a biased understanding of psychological problems such as depression, and they avoid treatment because they feel that "family ugliness cannot be made public." There are also some people who cannot seek medical treatment due to the relative lack of medical resources. Coupled with the influence of factors such as a certain missed diagnosis rate in medical institutions, the overall actual consultation rate of patients with depression is very low. Traditional diagnostic methods can only detect a subset of the many people with depression—the ones who come to a medical facility for help. That is, other people will face depression helplessly. Passively waiting for depression patients to seek help as is currently done will result in very low rates of consultation and depression will continue to rage. If medical institutions can take the initiative to look for patients with depression, such as directly conducting psychological surveys on college students, the rate of seeing a doctor will be greatly improved. Of course, the cost of doing so is relatively high. Consider that when a person seeks medical help for depression, the depression has already taken a toll on him, and treatment is more difficult. We need "active defense," which is to detect the person when the depressive tendencies are not too severe, so that help or treatment can be given in a timely manner.

The advent of the Web2.0 era and the emergence of online social media, such as blogs, campus social platforms, and other social networks, provide a place for many people with depression tendencies to vent their emotions. At the same time, based on the analysis of massive interactive information on social networks, we may provide a platform for actively discovering people who are prone to depression [2]. Especially as each high school has its own social platform, the students of the school publish information on the social network, and the campus management department can master a large amount of social network data. These data record students' thoughts, opinions, and details about their lives. By mining the massive data in the campus social platform, a lot of important information and knowledge can be found. In our recent online information observation on campus network online users, we found that some users, due to the high pressure of life, showed many psychological problems [3]. In severe cases, the language manifestations of depression and suicide occurred.

This paper will propose a classification model based on natural language processing and machine learning that takes into account both generality and accuracy, to actively and efficiently discover students with depression tendency from campus social platforms. The method proposed in this paper allows us not to wait for depressed patients to seek help, but to actively search for people with depression tendency from the crowd, which will enable medical institutions and nonprofit organizations to gain the initiative in fighting depression. Since the recognition process is completed automatically by computer, the speed and accuracy have unique advantages compared with manual work, so that we can quickly and timely find people who are prone to depression and can find the target in time, which greatly improves the efficiency of intervention [4]. For college students with high network activity, it is appropriate to use the method proposed in this paper to assess the state of depression. This method will greatly improve the ability of universities and other institutions to deal with students' depression, thereby reducing the harm caused by depression to the student population.

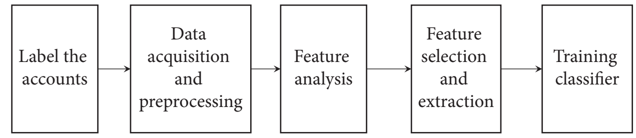

Figure 1: Classifier design process.

2. Identification Process

2.1. Model Design Idea. The campus social platform of colleges and universities is an important platform for students to communicate. It has the characteristics of huge user scale and convenient data acquisition. It is an important data source for campus management. Therefore, this paper selects users of a university campus social platform as the research object. Based on the data of campus social platforms, an effective method to automatically identify depression-prone users in campus social platforms is established. The process of model design is shown in Figure 1.

2.2. Annotated Account. This study is based on the assumption that "the language and behavior of campus social platform users who are prone to depression are different from normal users" [5]. To test this hypothesis, we first need to find a certain number of users who are prone to depression and normal users to establish a sample data set.

We randomly obtained a certain number of user IDs and manually labeled these accounts into two categories: "depressive tendencies" and "normal." In order to reduce the impact of class imbalance problem on the classifier, we do not keep the UID of all "normal" users. Then, the campus social platform information of these users is captured through the API provided by the Sina campus social platform, and after a certain preprocessing, it is used for training and testing the machine learning model. The labeling of the samples is done manually, and the process is as follows:

(1) Receive certain training, such as learning the basic knowledge of depression, diagnostic scales, and judgment of depression tendency.

(2) Groups that users with depression tendencies from campus social platforms may gather.

(3) Two of them independently annotated the obtained user set and divided the users into two categories: "with depression tendency" and "without depression tendency."

(4) The labeling results of the first two people were checked by a third person (the labeling rate was found to be more than 90% identical), and the labeling results were independently corrected.

2.3. Experimental Data Acquisition and Preprocessing. Data preprocessing is to process the original experimental data into experimental corpus that can be directly operated by the computer, and its operation mainly depends on the experimental data and algorithms. In this study, a supervised deep learning algorithm was used to perform binary

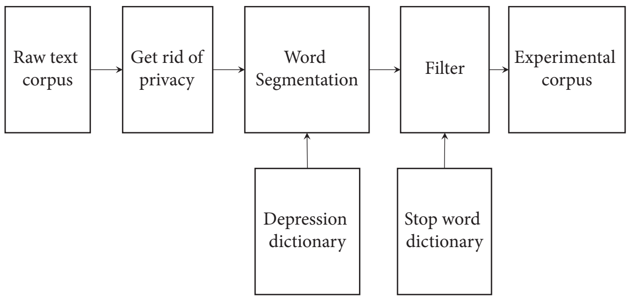

Figure 2: Text preprocessing process.

classification of text on campus social platforms, thereby realizing depression identification. Its preliminary work mainly includes labeling, word segmentation, denoising, feature, and algorithm selection; these operations have a direct impact on the subsequent experimental results. Reasonable preprocessing operations are a crucial step in text classification, and these operations are described in detail in this section.

Text preprocessing mainly includes word segmentation and denoising, and the specific process is shown in Figure 2. Since Chinese words do not have obvious delimiters like English words, it is necessary to divide sentences into words one by one through word segmentation. The language expressions of campus social platforms are relatively casual and do not strictly follow traditional language norms and often insert special symbols [6]. It belongs to the text with high noise content, and denoising processing is very necessary.

This experiment uses Jieba word segmentation implemented in Python to segment the text. Jieba comes with a dictionary containing more than 20,000 Chinese words, and its word segmentation speed and effect are relatively good. This experiment adopts Jieba's precise mode, which combined with the domain dictionary can cut the experimental data more accurately, which is suitable for text analysis of campus social platforms. In order to further maintain the integrity of the semantics, some domain terms and network neologisms are avoided to be excessively segmented [7].

2.4. Feature Selection. Data features are the main internal factors affecting text classification, and reasonable feature selection can effectively improve the accuracy of experiments. By researching and analyzing the characteristics of the "tree hole" campus social platform, referring to depression-related materials, we conducted in-depth mining from two aspects of the text itself and extended information and comprehensively extracted the characteristics closely related to the depression campus social platform. In terms of content, it mainly includes two features, namely, the semantic features of the text itself and the dictionary features. In addition, some features expanded from the content can also reflect the behavior of the campus social platform of depression [8]. To sum up, the features selected in this paper mainly include three modules: semantic features, extended features, and dictionary features. The specific description is shown in Table 1.

These three characteristics are described in detail below.

Semantic features refer to the semantic information contained in the text itself, which can reflect the structure and contextual semantic relationship and reflect the publisher's expression form and overall emotional trend, which is of great significance for recognition. This part of the features will be automatically extracted by deep learning algorithms. Dictionary feature is whether the text contains dictionary words. The anomalies of these campus social platform texts are mainly reflected in two aspects: emotion and behavior. For example, it contains a large number of negative words such as "pain," "life is better than death," and various kinds of thought expression and suicide methods such as "want to die," "cut your wrist," and "burn charcoal" are also frequent sentences in the "tree hole." These sensitive words fully reflect the patient's condition, so the dictionary features of these words are very important.

In this paper, a dictionary database is constructed for the field of depression campus social platform. The specific dictionary features are described in Table 2.

Affected by depression, the campus social platform behaviors of depressed patients have some notable characteristics, which are extended from the campus social platform content, so they are called extended characteristics, for example, the release time of the campus social platform, the length of the text, etc. These extended features are closely related to the symptoms of depression, and only by fully mining these valuable features can the identification of depression be optimal [9]. Through a comprehensive analysis of the symptoms of depression and the characteristics of the campus social platform, it is found that the text of the campus social platform for depression has many individual and abnormal characteristics and further artificially extracts each extended feature. The main features are as follows:

(1) Through statistical analysis, the most frequent update time is from 10:00 pm to 2:00 am.
(2) The language expressions of depression patients on campus social platforms are more casual, the format is not standardized, and the length is generally shorter.
(3) Depressed patients pay less attention to the outside world, and the general campus social platform is original.
(4) Depression is more self-focused, interacts with others, and pays less attention to others, while the first-person singular "I" is often used in language, and the plural "we" is used less.
(5) Patients frequently use emoji and some suicide-related symbols on campus social platforms.
(6) Depression is more inclined to be puzzled and rhetorical about life experiences on campus social platforms and use questions more frequently.

3. Depression Recognition Model

This paper designs three different models for student depression identification.

Table 1: Features and definitions.

Features	Definitions	Example
Semantic features	Semantic information of text expressions on campus social platforms	Text itself statement
Extended features	Expanded features strongly associated with depression in campus social platforms	Time, length, originality, etc.
Dictionary features	Sensitive vocabulary that reflects depression tendency contained in campus social platforms	Sentiment dictionary, keyword dictionary, etc.

Table 2: Dictionary features.

Feature		Feature definition
Dictionary features	Sentiment dictionary features	Whether contains the vocabulary of the emotional dictionary
	Emoji dictionary features	Whether contains the vocabulary of the emoji dictionary
	Mood particle dictionary features	Whether contains the vocabulary of the modal particle dictionary
	New word dictionary features	Whether contains the vocabulary of the online new word dictionary
	Keyword dictionary features	Whether contains the vocabulary of the keyword dictionary
	Suicide tool dictionary features	Whether contains the vocabulary of suicide tools dictionary
	Dictionary of behavioral symbols	Whether contains the vocabulary of the behavioral symbol dictionary

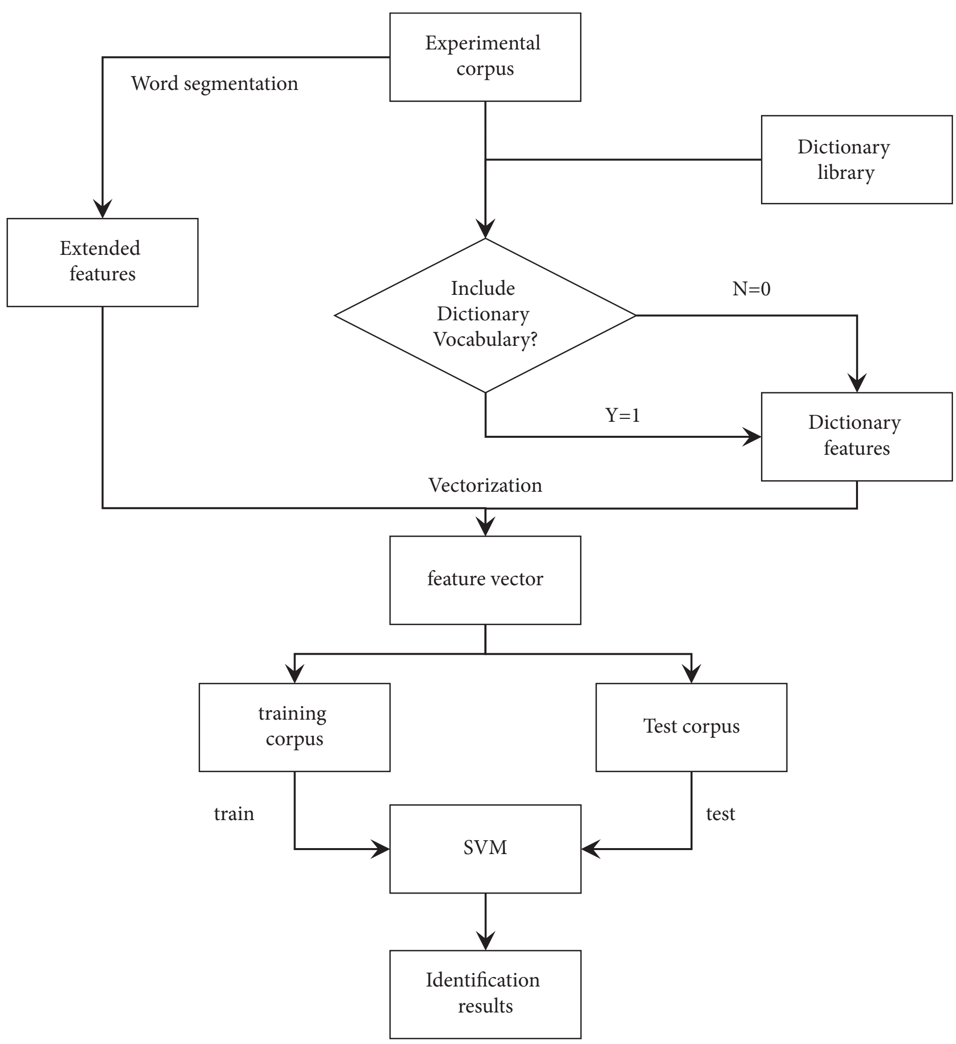

Figure 3: Identification algorithm based on SVM.

3.1. Depression Recognition Algorithm Based on Support Vector Machine. The input to the support vector machine algorithm is a vector, so the features need to be vectorized first [10]. In this paper, the support vector machine algorithm is used to classify text based on extended features and dictionary features, so it is necessary to vectorize these two features. The specific vectorization rules are as follows: In the extended feature, the description length of the campus social platform, the number of interactions on the campus social platform, the degree of social activity, the degree of collective attention, and the degree of self-attention are themselves numbers. Whether it is original, whether to use a positive expression map, and whether to use a negative expression map, the value of the feature value is 1, otherwise 0. The time feature is divided into day and night, corresponding to 1 and 0. All dictionary features are the number of corresponding dictionaries; if not, take 0.

The algorithm implementation process based on SVM is shown in Figure 3.

The SVM-based student depression recognition algorithm is as follows:

(1) Feature selection and vectorization: According to the feature selection and vectorization rules introduced above, on the preprocessed experimental corpus, Python language programming is used to realize the selection and vectorization of extended features, and the dictionary features are obtained by scanning the dictionary library.

(2) Model configuration: The experimental tool uses LIBSVM (A Library for Support Vector Machines) integrated tool for text classification experiments, which is the most widely used SVM algorithm tool developed by the Institute of Information Engineering, National Taiwan University. The tool is written based on C language, including standard SVM algorithm, probability output, support vector regression, multiclass SVM, and other functions and has call interfaces in JAVA, Python, R, MATLAB, and other languages. It is a relatively hot tool at present, and the experimental speed and effect are relatively good. This experiment calls the Python interface for model training.

(3) Model training and testing: The corpus is divided into training corpus and test corpus according to the ratio of 7:3, in which three types of dictionary features, extended features, dictionary features, and extended feature fusion, are trained and tested. The optimized parameters and training corpus are used as input for model training, and then the generated model is tested through the test corpus to output the experimental results.

3.2. Depression Recognition Algorithm Based on Convolutional Neural Network. The convolutional neural network model structure mainly contains five layers, each layer has its own function and is connected before and after. The input layer is used to input the processed matrix vector, which is converted from the word vector of the text. The main component of the convolution layer is a feature extractor (convolution kernel), which is mainly used to extract features and output feature maps. The convolution layer can contain multiple layers, and the front and rear layers are connected to each other. The pooling layer is mainly used to process a large number of feature maps output by the convolutional layer to reduce the amount of data while maintaining important feature information. The fully connected layer converts the features extracted by the previous layers into one-dimensional features [11]. The output layer takes the one-dimensional features of the fully connected layer as input and then uses a classification algorithm for classification, such as softmax logistic regression. The specific description of each layer is as follows:

The input layer is used to obtain experimental data, and the input of the convolutional neural network for text classification is a matrix vector. Therefore, it is necessary to convert the vocabulary into a vector and use the word vector of each word in the sentence as a row to form a matrix vector of the sentence. Convolutional layers are the fundamental operations in convolutional neural networks. The convolution operation is actually a mathematical operation. This operation generally includes input, kernel function, and output feature map. Convolution is a local operation, and the local feature information of the data is obtained by applying a certain size of convolution kernel to the local area of the input data. Pooling layers are nonlinear downsampling algorithms. The pooling function replaces the data at the position with the overall statistical value of the adjacent data at the current position, which plays a dimensionality reduction role and ensures that the output data does not change much. Commonly used pooling functions are the maximum pooling function and the average pooling function. The fully connected layer is to stitch together the two-dimensional feature vectors output by the pooling layer and output the probability of each category through the softmax layer.

This paper uses the word2vec tool to generate word vectors, and reasonable parameter selection can effectively improve the training efficiency. In this paper, based on the specific conditions of the experiment, several important parameters are selected as follows: Compared with the CBOW model, the training time of the Skip-gram model is longer, but the accuracy is generally better than that of the CBOW model. Considering that the experimental corpus is relatively moderate, in order to obtain better experimental results, the Skip-gram model is selected for this experiment. Depending on the size of the context window of the word, the reflected information is also different. Generally, a small context window is more conducive to learning contextual semantic features and relationships. According to the characteristics of the experimental corpus, this paper adopts two values of 5 and 10, respectively. The training algorithm of the experiment adopts softmax, which has better effect with rare words and is suitable for the scene of this experiment. The specific parameters are shown in Table 3.

The experimental process based on convolutional neural network is as follows:

Table 3: Model parameters.

Parameter	Definition	Value
Sentences	Can be a list, transformed from the original corpus	Depression campus social platform corpus text
Sg	Used to set the training algorithm, 0 corresponds to the CBOW algorithm, 1 corresponds to the Skip-gram algorithm	1
Size	Refers to the dimension of the feature vector	200
Window	Indicates the maximum distance between the current word and the predicted word in a sentence	5, 10
Hs	1 corresponds to hierarchical softmax algorithm, 0 corresponds to negative sampling algorithm	1

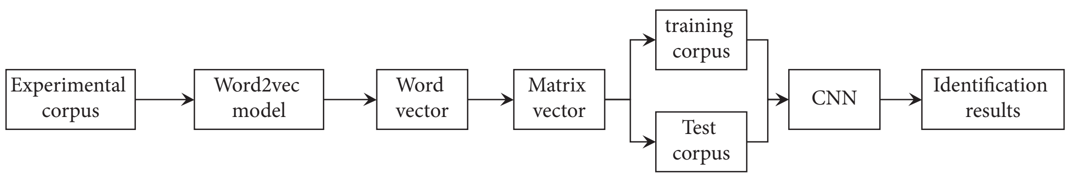

Figure 4: CNN-based recognition process.

(1) Word vector generation.

(2) Model parameter configuration: The algorithm used in this experiment is TextCNN, which is implemented in Python language based on the TensorFlow framework.

(3) Model training and testing: Divide the preprocessed experimental corpus into training corpus and test corpus in a ratio of 7 : 3, and use convolution kernels of 2, 3, and 4 to conduct experiments. First, the TextCNN model is trained through the training corpus and finally test corpus test model.

The whole recognition process based on convolutional neural network is shown in Figure 4.

3.3. Depression Recognition Algorithm Based on Dual-Input Convolutional Neural Network. As a shallow machine learning, support vector machine has better classification effect based on shallow extended features and dictionary features [12]. Convolutional neural network, as a deep machine learning algorithm, can automatically extract semantic features of text sequences for fast learning and efficient classification. However, neither of these two algorithms is compatible with all features at the same time, which reduces the recognition rate of depression to a certain extent. Expanding compatibility is the core of solving the above problems. This paper improves the convolutional neural network algorithm to achieve compatibility with all features.

By analyzing the model structure of the convolutional neural network, it can be found that its convolutional layer and pooling layer automatically extract features and feature dimension reduction for the input data, respectively. Finally, the extracted features are processed based on the full connection layer, and the predicted values are output through the full connection layer. The output is equivalent to all the features automatically extracted by the convolutional

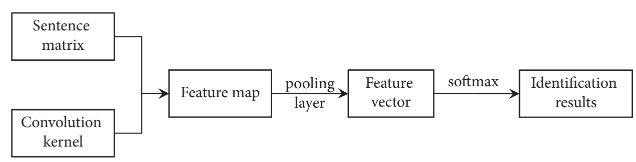

Figure 5: DI-CNN model structure.

neural network and finally classified by the output layer. Based on this, this paper proposes a dual-input convolutional neural network (dual-input-CNN, DI-CNN for short) algorithm. Its core idea is that the first four layers of convolutional neural network are unchanged; only the results of the full connection layer are integrated with the feature vector formed by the fusion of extended features and dictionary features and then classified through the softmax layer, so as to realize all feature fusion as input. The model structure is shown in Figure 5.

3.4. Experimental Results. In order to verify the influence of depression dictionary on depression recognition, the experimental evaluation standards used in this paper are precision rate P (precision), recall rate R (recall), and F-measure (F-measure) as evaluation standards. All experiments in this paper use this criterion, and they are defined as follows:

$$P = \frac{T}{E},$$
$$R = \frac{T}{N}, \tag{1}$$
$$F = \frac{2 \cdot P \cdot R}{(P + R)},$$

where T is the number of correctly classified samples; N is the actual number of samples of a certain category; E is the

Table 4: Experimental results.

Feature combination	P	R	F
Extended feature + dictionary feature + SVM	0.8280	0.7875	0.8072
Semantic features + CNN	0.6847	0.5507	0.6106
Extended feature + dictionary feature + semantic feature + DI-CNN	0.8305	0.8348	0.8321

number of samples predicted by the classification model as a certain category. The experimental results are shown in Table 4.

The experimental results and graphs show that the recognition rates of the three algorithms are DI-CNN, SVM, and CNN, respectively. At the same time, comparing SVM and CNN separately, the effect of SVM is better, which further shows that the artificially extracted shallow features have a better effect on the recognition rate of depression.

4. Application Prospects of the Model

The first threshold of depression treatment and research is identification. The identification of depression in this paper is only a preliminary judgment on whether there is a tendency to depression. However, in practical applications, this is only the initial stage, and the relevant medical staff still need to dig deep into the patient's situation. It mainly involves the following aspects: the cause of depression, the type of disease, the severity of the disease, etc. In fact, on the social platform, the campus social platform that is updated at high speed every day contains the daily life trajectories and emotional ups and downs of users. Fully mining this information can greatly reduce the workload of people and assist medical staff to implement treatment quickly and accurately. Therefore, in-depth analysis of the campus social platform for patients with depression can be carried out in the following aspects in the future:

(1) Mining user information based on the time dimension: Identification based on a single campus social platform will lead to fragmented information, and it is impossible to comprehensively obtain the patient's condition. From the perspective of time, track the campus social platform dynamics of a campus social platform user for a period of time, and comprehensively analyze their life trajectory and emotional fluctuations during this period, as well as the relationship between the two. In this way, it is easy to find the cause of the user's illness and further infer the patient's disease type.

(2) Mining user information based on spatial dimensions: tracking the location information disclosed by patients on campus social platforms and analyzing the user's environment, personal identity, surrounding crowd, and other information based on this spatial information. It can not only assist in judging the cause of the user, but also provide rescue information for rescuers.

(3) Depression grade assessment: Depression patients have different degrees of illness; some are in the initial stage of mood swings, while others may have serious suicidal tendencies. By grading depression, it is possible not only to quickly locate those patients with suicidal tendencies and take rescue measures, but also to prevent those primary ones in advance.

To sum up, further build a depression rescue chain with the school social platform as the core, fully tap the text information on the platform with the help of natural language technology, and monitor and extract the following user information: 1. The user's symptoms, etiology, degree of illness, and whether there are suicidal tendencies; 2. Personal information, social relations, time, and space. Based on this, the patient's condition and information knowledge map are, respectively, constructed to realize the full integration of technicians, medical personnel, psychologists, and rescuers. The knowledge map is mined and constructed by technical personnel, analyzed and diagnosed by medical personnel, and treated and psychologically counseled by medical personnel or psychologists according to different situations. If there is suicidal behavior, rescuers can quickly locate and rescue through the user information knowledge map. This will be the development direction of college students' depression identification and treatment.

5. Conclusion

In view of the current problems in depression identification, this paper proposes a depression identification method based on campus social platform text and deep learning. It not only effectively avoids the problem of patients not taking the initiative or cooperating, but also can obtain sufficient data for research. This method of turning passive into active discovery reduces the harm caused by direct diagnosis of patients and provides support for medical staff to quickly identify and treat patients. At the same time, in order to improve the feasibility and recognition rate of the algorithm, this paper has made the following improvements:

(1) The construction of the dictionary: fully excavate the vocabulary of depression on social platforms, and combine the characteristics of depression patients with negative emotional tendencies and suicidal tendencies in actions to construct three major emotional dictionaries, behavioral keyword dictionaries, and behavioral dictionaries. Suicide-related dictionaries are gathered into a comprehensive dictionary library for the depression campus social platform, which makes up for the lack of dictionaries in this field.

(2) Feature selection: Depression blogs have their own features, not only in the text itself, but also in some extended features that are closely related to

depression. This paper fully integrates semantic features, dictionary features, and extended features to ensure the optimal recognition rate of depression.

(3) Algorithm improvement: Based on the three selected feature modules, support vector machines and convolutional neural networks were used for experiments, but these two algorithms were not compatible with all features at the same time. Therefore, this paper proposes an improved two-input convolutional neural network, which realizes multifeature fusion input, and further improves the experimental effect.

Through comprehensive analysis and experiments, this paper still has some shortcomings, mainly involving the following two aspects:

(1) Although this paper extracts relevant features more comprehensively, the influence of each feature is different; for example, dictionary features, time in extended features, and other features can better reflect whether the user suffers from depression. Therefore, it is very necessary to weight each feature, which is also the next research direction.

(2) The convolutional neural network used in this paper is suitable for short text classification. Although most of the campus social platforms are short texts, there are also users who use long sentences to describe their situation comprehensively. At this time, it is easy to cause the mining of these information. Therefore, follow-up research can select different deep learning algorithms according to the length of the blog. If it is a long blog we can use a recurrent neural network.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Research on Collaborative Innovation of Animation Specialty in Colleges under Digital Technology

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Digital technology plays an important role in promoting the development of the animation industry. With the rapid development of digital technology in China, the wide application of digital technology in the animation field has become a new method of animation production, which also is an important way for the development of animation major in colleges. This paper studies the collaborative innovation of animation majors in colleges under digital technology, combined with the driving effect of digital technology on animation major, and a collaborative innovation system of animation major based on digital technology is constructed. Based on this, a collaborative innovation platform for animation projects is designed, which is dominated by universities and supplemented by governmental enterprises. The basic functions of animation knowledge integration, animation knowledge maintenance, animation knowledge retrieval, and animation knowledge sharing are implemented. The platform not only innovates the teaching mode of animation major in colleges but also promotes the development of the animation industry, which has practical applicated value.

1. Introduction

Animation industry is the core industry of global economic development in the 21st century and is also a way of inheriting traditional Chinese culture [1]. The animation technology specialty has strong social practicality, which is of great significance for training animation professionals and promoting the development of the animation industry. At present, the enrollment of animation major in colleges is increasing year by year, with wide coverage and gradually increasing teaching difficulty. How to promote the reform of education in digital animation has become a problem faced by higher vocational colleges in China. The development of the animation field cannot be separated from computer technology, which is an important part of the animation field [2]. Under the influence of economic globalization, the wide application of computer technology in collaborative innovation of animation specialties is not only a sign of the arrival of the era of science and technology but also an effective measure to promote its evolution. The driving effect of computer technology is mainly reflected in computer technology in 3D animation, animation synthesis, paperless animation, and other fields [3]. On the one hand, the technology of virtual reality has been implemented in the animation field through computer technology; on the other hand, it has also achieved the development of other related industries. Therefore, the wide application of computer technology not only expands the expression space of animation, enriches the expression forms of animation works, and improves the efficiency of animation creation but also promotes the innovation of the animation industry, the spread of animation works, and the development level of the animation industry, which is conducive to the further advance of China's animation design industry.

2. Construction of Collaborative Innovation System of Animation Specialty in Colleges under Digital Technology

At present, the concept of animation design in China is relatively simple, with lack of innovation ability in the animation industry not high, and the design it is monotonous [4]. Science and technology, intelligence, and electronization are the main trends of the animation industry in the future. Traditional computer technology can only fulfill 2D animation and graphic animation, while the application of digital media technology makes animation design and production efficient, which greatly promotes the development of China's animation industry.

Collaborative innovation of animation specialty in colleges under digital technology needs to build a third-order practical teaching system, in progress, of professional skill studios (graphic design, animation production, and VR), animation R & D center, and entrepreneurial base for college students based on the curriculum design of animation major in colleges, as shown in Figure 1.

The collaborative innovation system of animation is based on animation practice, which cultivates professionals through skill training, animation research and development, and incubation base construction. Of course, the innovation and development of the animation major require not only the drastic reform of the course teaching in colleges and universities but also the cooperation between the government and enterprises and the collaborative innovation of the three parties above. Only in this way can we achieve the goal of cultivating professionals in animation.

Colleges should make use of digital technology to carry out public courses, professional courses, and postpractice to carry out the training of basic skills. They also need to design open practice for students of different levels and apply three-dimensional software, such as ZBrush and 3Dmax to the design of creative animation, model animation, and the achievement of teaching effect and evaluation [5]. Constantly, colleges are supposed to cultivate the consciousness of integrating diversified science and technology into animation production and design, among students, so as to improve their comprehensive ability and lay the foundation for their entry into the animation industry.

Enterprises should provide internship positions for students majoring in animation and set up three studios [6] for graphic production, 3D animation, and postproduction. They need to fully popularize the teachers by using AR technology according to the requirements of technical staff in enterprise and set up various technical centers such as hand-painted galleries, holographic projection, and animation industry base, to ensure more effective innovation of digital technology from a developmental perspective and the cultivation of professionals learned in the new era.

The government should provide more practical opportunities for students majoring in animation through policy inclination, give full play to the government's role as an organization and bridge, formulate supporting policies for related enterprises with school-enterprise cooperation, ensure full supervision and evaluation, and ensure the integration of production and education [7].

Under the background of digital technology, only through the deep cooperation of government, universities, and enterprises, the use of modern digital technology, the integration of manpower, material resources, and technology, and the establishment of a collaborative innovation platform of animation production technology can the innovation and practice of animation specialty be promoted.

3. Design of Collaborative Innovation Platform for Animation Projects Based on Digital Technology

Economic globalization promotes the development of technological innovation and the design of animation industry towards globalization, decentralization, and synergy, while knowledge is becoming an important element of the development in animation [8]. The animation industry involves the integration of technologies in computers, networks, process of graphics and images, signal processing, and other fields. It also includes basic techniques of digital media, a platform of digital media, service technology, and technology of application in the digital media field [9]. Combined with the collaborative innovation system of animation major, it is necessary to integrate the assets of universities, enterprises, and governments into their own systems and reorganize the animation assets of these parties in the form of knowledge, so as to really play their role and to build an ontology-based collaborative innovation platform for animation projects, which provides an online communication channel for universities, enterprises, and governments.

3.1. Demand Analysis. In the process of collaborative innovation of animation, knowledge is distributed in universities, governments, enterprises, and other units, involving a wide range. Knowledge about animation is also distributed in various departments, such as personal computers, enterprise servers, archives, personal minds, backup data, and the Internet. [10]. How to integrate scattered knowledge and realize exchange and sharing is a difficulty [11]. This study tries to integrate the animation resources of universities, governments, and enterprises and provides diversified paths for collaborative innovation of animation majors in universities by constructing a collaborative innovation platform; therefore, the platform needs to implement the following basic functions:

(1) Expression of animation knowledge: individual knowledge is one of the important sources of unit knowledge. Animation knowledge in universities, governments, enterprises, and other departments has its unique storage format. If animation knowledge is expressed and formalized randomly, it will cause the problem of knowledge heterogeneity [8]. Therefore, it is necessary to clarify the expression and formalization of animation knowledge, form a specific format of sublanguage and ontology library, and build a common ontology so as to provide a theoretical basis for the expression and formalization of individual knowledge, thus effectively reducing the heterogeneity of knowledge.

(2) Maintenance of animation knowledge: the maintenance of a date is an indispensable function for any knowledge application [12]. Collaborative innovation of animation major in colleges is a dynamic

process, and the discovery and updating of knowledge in the development process are inevitable. It is usually impossible to abstract and solidify all knowledge at the beginning of a project. Therefore, it is necessary to maintain and handle animation knowledge in good time. Therefore, this improves the expandability of the collaborative innovation platform of projects.

(3) Animation knowledge retrieval: the knowledge retrieval function of animation is the main means for users to acquire animation knowledge from the system, which is realized by querying, and it is also the main function of the collaborative innovation platform of animation projects that needs to be implemented.

(4) Animation knowledge sharing: actually, animation knowledge does not exist independently of data. Animation knowledge and data complement each other in supporting decision-making or information sharing. Universities, governments, enterprises, and other departments have different demands for animation resources, and their own animation resources may be lacking in other units [13]. Therefore, animation knowledge sharing is the core function of a collaborative innovation platform for animation projects, which can provide effective support for the innovative behaviors of universities, governments, and enterprises.

3.2. Overall Deployment. Through the design of the collaborative innovation platform of the animation project, all units involved in the collaborative innovation of animation specialty are connected with related knowledge (including explicit knowledge and tacit knowledge). Also, through the organization, management, and sharing of animation knowledge, participants can comprehend the dynamic development of animation specialties in time and all kinds of animation knowledge needed by their own, which provides a good managing platform for the spread of animation experience and knowledge.

There are many units and participants in the professional collaborative innovation of animation, and there exists independence among participants in time and space. Therefore, under the network environment, establishing a collaborative innovation platform for animation projects based on WEB can effectively realize the integration of knowledge flow, information flow, and business flow, which can promote sharing and management. If it is the general knowledge of animation project ontology or the hidden animation knowledge published on Wiki, blog, forums, etc., it needs to be packaged into the knowledge portal to meet the needs of users [14].

The animation collaborative innovation platform includes a physical network layer, infrastructure layer, basic service layer, service layer, user layer, and terminal, and the specific deployment is shown in Figure 2. Among them, the terminal is the basic interface between users and the system, which needs to reflect the basic needs of users [15]. Applications in the basic service layer are the core of the whole system [9].

3.3. Functional Design. Combined with the demand analysis and overall design of the animation collaborative innovation platform, its core functions are divided into animation knowledge integration, animation knowledge retrieval, animation knowledge maintenance, and animation knowledge sharing.

3.3.1. Animation Knowledge Integration. The animation collaborative innovation platform needs to gather information from universities, governments, and enterprises, which is stored in their respective databases and exists in the form of various business systems. In order to unite these units and integrate the advantages of animation resources, they ought to introduce the concepts of enterprise's dynamic alliance and project's cooperative subcontracting and integrate the process of animation knowledge [10]. At present, the animation industry's information systems of universities, enterprises, and governments are still mainly supported by relational databases. D2RQ provides a complete set of APIs to realize the access of relational databases to the semantic Web [16]. For us to transform the legacy data into RDF data [17], which has a higher semantic level and can be processed by knowledge processing, with the help of D2RQ, the animation knowledge of universities, enterprises, and governments is integrated and transformed, as shown in Figure 3.

In addition, during the development of the collaborative innovation platform for animation projects, many metadata, metaknowledge, business rules, and so on of animation majors are based on XML. Therefore, the animation knowledge contained in XML occupies a large proportion and takes up an important part of the collaborative innovation platform for animation projects, which must be considered. On this basis, an XML-based file is proposed to describe the organization and functions of enterprises, and it is integrated into the collaborative innovation platform of animation projects. The relationship between XML files and entities is constructed by MAPONTO technology, and the mapping is implemented by the Company owl ontology, and the mapping of the collaborative innovation platform of animation projects is realized on this basis [18]. The mapping from the XML document to ontology is shown in Figure 4.

3.3.2. Maintenance of Animation Knowledge. It takes a long time to develop animation projects in colleges, and animation knowledge is constantly updated and changing. Therefore, how to make ontology adapt to the changes of the outside world and maintain it in time [19] is an unavoidable problem in the management of animation knowledge by using ontology at present.

With respect of colleges and universities, the development of animation projects is a temporary process. After the development cycle of each project, the temporary alliance

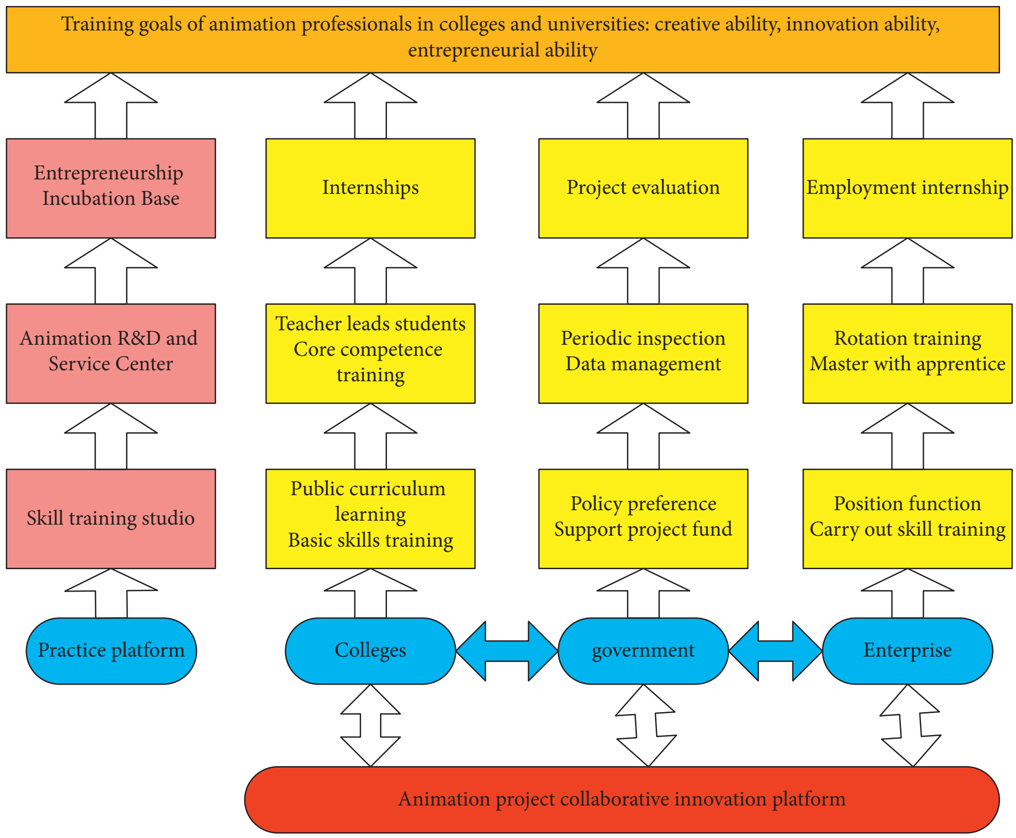

FIGURE 1: Collaborative innovation system of the animation specialty in colleges and universities based on digital technology.

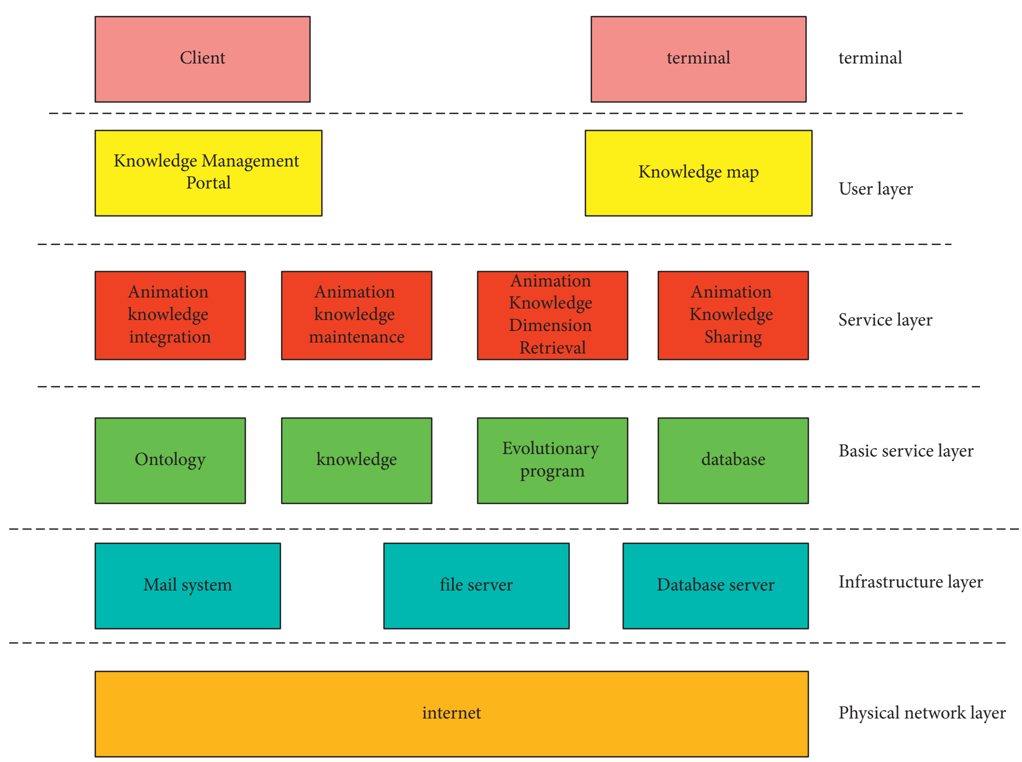

FIGURE 2: Deployment of collaborative innovation platform for animation projects.

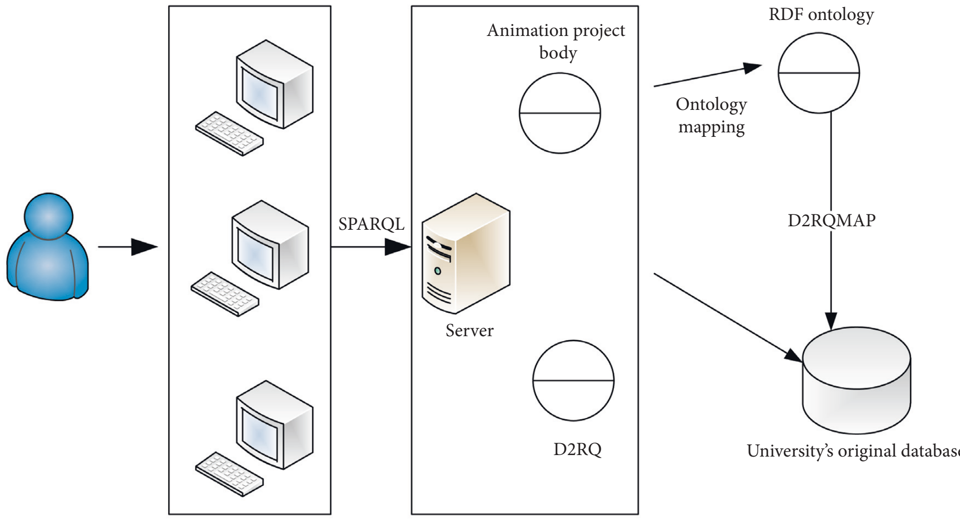

Figure 3: Data conversion of an animation specialty based on D2RQ.

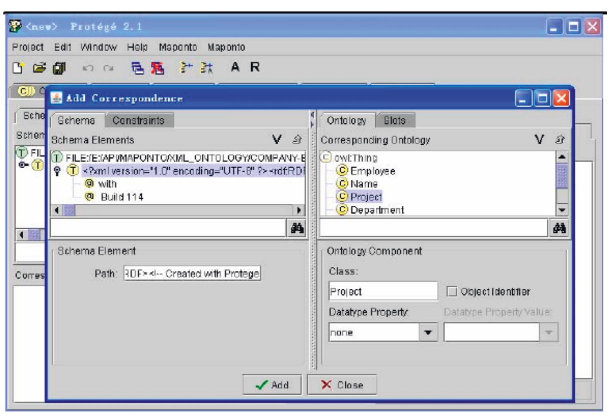

Figure 4: Mapping XML documents to ontology.

formed when participating in the project will be disintegrated. However, the experience of animation projects is sustainable. Compared with previous projects, the next development is different in creativity and production. However, its core technology is relatively stable [20]. Therefore, it is necessary to maintain the knowledge of animation design in each stage, which is mainly represented by the tasks of reusing, updating, and revising animation knowledge. However, up to now, the maintenance of the animation knowledge in colleges is only formal knowledge, and the most important thing is the ontology of animation major. The knowledge maintenance module is centered on the ontology of animation projects, and it updates and maintains knowledge in various ways on the basis of ontology evolution [21]. The ontology of animation projects provides a vocabulary collection in public for the development of animation projects, while the evolution of ontology is a method and technology, and combining the two is the best solution.

3.3.3. Animation Knowledge Retrieval. Establishing collaborative innovation platform for animation projects is to fully tap and utilize animation knowledge mastered by organizations and apply animation knowledge to project development so as to achieve the purpose of improving the efficiency of animation production. An excellent knowledge management system requires not only massive structural knowledge but also a good platform, which can convey the best knowledge to people who need it most in the shortest time, and the key is how to search and query. The knowledge query of the animation collaborative innovation platform is based on ontology, and the design of the knowledge retrieval module should fully consider the actual needs of users so that users can better understand the semantics of the knowledge they have learned and carry out the semantic query according to the vocabulary, semantic relations, and restrictions [22].

There are three retrieval methods of animation knowledge in the collaborative innovation platform of animation projects:

The first is an inquiry by browsing [23]. The system uses the visual interface, takes the animation project ontology as the main body by the built-in retrieval function, and passes the existing retrieval function to retrieve the current content. For example, when the user clicks "Personnel," the system will provide feedback information about people, such as who is in this project, which department it belongs to, and what is its responsibility? Compared with traditional information retrieval, it uses ontology-based semantic relations more and integrates scattered information, thus facilitating users' understanding of existing projects.

The second is customized inquiry. The user selects the corresponding words and associations and then generates a semantic query [11] on the interface given by the system. Compared with traditional methods, it is more flexible for users who do not need to know the syntax details of ontology queries. However, users must better understand the ontology and customize the query conditions and restrictions.

Third is advanced inquiry [24]. Advanced queries refer to advanced users who have some knowledge of the SPARQL language. It can directly organize and input SPARQL to query, analyze, and process them. Compared with the previous two methods, it requires users to be more familiar with SPARQL syntax and be able to write corresponding queries according to their own query requirements.

The basic flow of animation knowledge retrieval of the animation collaborative innovation platform is shown in Figure 5.

When searching for knowledge, the animation project ontology is like a conceptual view, and users do not need to know its internal structure. Ontology can hide the differences in animation professionals' knowledge, and it can become the source of animation knowledge by connecting with ontology through reasonable ways.

3.3.4. Animation Knowledge Sharing. In order to realize the collaborative innovation of animation major in colleges, we should not only achieve the interchange of data but also share and exchange knowledge levels. Due to a poor function of semantic expression, it is very difficult to exchange and cooperate knowledge among various units, while Web technology based on ontology and semantics can effectively solve this problem [25].

Knowledge sharing is the most important demand and one of the most important functions in the process of collaborative innovation platform. Compared with the traditional business model, the interactive relationship among enterprises, departments, and individuals in animation projects is a thorny issue [26]. In this study, the general animation knowledge of collaborative innovation platforms for animation projects is structured and formalized, which provides a basis for sharing and describing other knowledge and realizes the unification of knowledge. On the one hand, sharing animation knowledge refers to the ability to provide relevant information to different characters, which, on the other hand, is the sharing and dissemination of personal animation knowledge [27]. Therefore, the animation knowledge sharing process is designed as shown in Figure 6.

From Figure 6, it can be seen that animation knowledge can be published and pushed through the Web page, and users can give timely feedback according to the pushed information, which forms a circular data sharing process.

3.4. Database Design. The database is the keystone of the collaborative innovation platform of the animation project. In the development of the platform, many descriptions need to be supplemented by data.

On the one hand, all kinds of structured data about projects in collaborative innovation platforms of animation projects need to be stored in database. Only when data are used in combination with the knowledge described in ontology or business rules can they truly reflect the value. Therefore, it is necessary to create a mechanism to unify the management between data and knowledge, which provide a basis for users to better understand and use them. The collaborative innovation platform of animation projects mainly involves the ecological chain of animation Industry-University-Research, including design technology of animation modeling, researching mechanism of animation product, Chuangzhi Microsoft Technology Center, animation research and development center, laboratory of application in digital media technology, institutions of animation technology research, etc. The table of collaborative innovation platforms for animation projects is constructed, as shown in Figure 7.

On the other hand, the collaborative innovation platform of animation projects needs to be connected with the original system of colleges. The data accumulated in legacy systems contain much information related to the development of animation projects. Reusing and integrating of this information is also very important. To this end, the animation collaborative innovation platform should own an interface with the database so that users can simultaneously get the corresponding data when accessing knowledge; thus, the efficiency and quality of decision-making are improved. The database and ontology linked by mapping can implement the data sharing between the collaborative innovation platform of animation projects and other systems, as shown in Figure 8.

4. Application of Collaborative Innovation Platform for Animation Projects Based on Digital Technology

The development of an animation collaborative innovation platform has practical value and a broad prospect in the application.

4.1. Innovating Animation Teaching Mode. The animation collaborative innovation platform of the project contains abundant animation knowledge. By docking with the learning platform of animation courses in colleges, it can form a display platform of teaching achievement in animation. The platform includes the creation of 2D short films, 3D short films, and microfilm, as well as the appreciation of students' works and other columns. Students can learn the basic knowledge of 2D animation, create a two-dimensional animated short film, and upload it to the learning platform. With the basic learning of 3D animation, students can apply 3D animation technology to complete the production and demonstration of 3D animation. At the same time, special columns can be set up for students to shoot short videos and display animation technology at a higher level after mastering the basic knowledge of micromovies, which will be evaluated by teachers and classmates to show their capacity.

In addition, with the help of the collaborative innovation platform of animation projects, teachers can further extend and form a modular teaching process of computer animation specialty, which integrates basic theory teaching, creation of 2D animation short film, comprehensive design of 3D animation short film, creation of microfilm, design of digital illustration, and practical training, so as to cultivate students' professional interest and innovation and improve their professional skills in practical operation, which

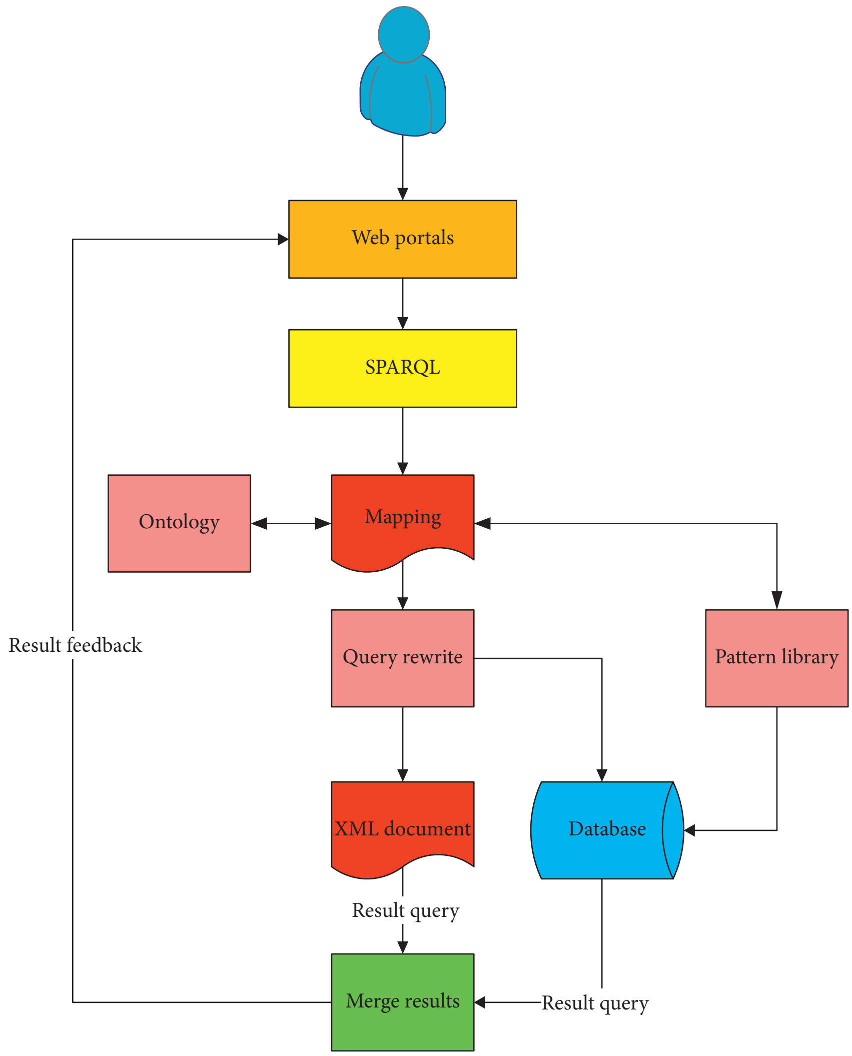

Figure 5: Basic processing flow of animation knowledge retrieval.

provides a practical teaching mode for training technology professionals.

4.2. Promote the Development of the Animation Industry. The collaborative innovation platform for animation projects integrates the communities of shared interest among government, enterprises, universities, etc., which takes the training of animation professionals as the starting point, serves society as the value orientation, and integrates society, industry, and education in the same field. Among them, the government, as a manager, provides policy and institutional and environmental support for the cooperation between universities and enterprises through "tangible hands." As the core element of the market economy, enterprises provide financial support for technical research through technology industrialization and use modern industrial colleges to transform human capital into economic profits. As the primary body in modern industrial colleges, colleges and universities pursue social values and are responsible for training high-quality skilled talents, delivering talents to society, and meeting the market demand for talents. So, balance the value orientation of the three is an important premise for collaborative innovation of the animation specialty.

The collaborative innovation platform of the animation project has formed a collaborative innovation model where the government takes the leading role and the school-enterprise is the main body. It has fully played the coupling effect of the industrial chain and the education chain, which enhance the dominant position of the school-enterprise in the collaborative innovation and collaborative education of modern industrial college, and then realized the effective allocation of innovation resources.

Animation project collaborative innovation platform should not only meet the needs of the government, enterprises, and universities but also be the fundamental guarantee for the survival and development of the animation industry. Through modern computer technology and communication technology, we can build enterprises a collaborative innovation platform for animation projects, which may customize a platform environment with information interaction, collaborative cooperation, and management for the government, enterprises, and universities. It is meant for

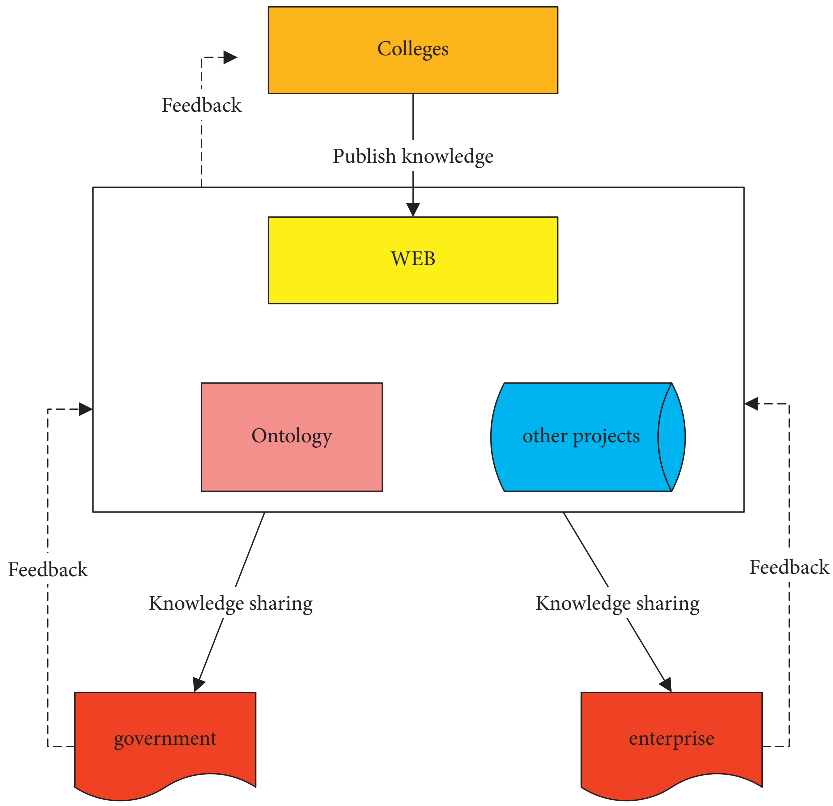

Figure 6: Sharing of ontology-based animation knowledge.

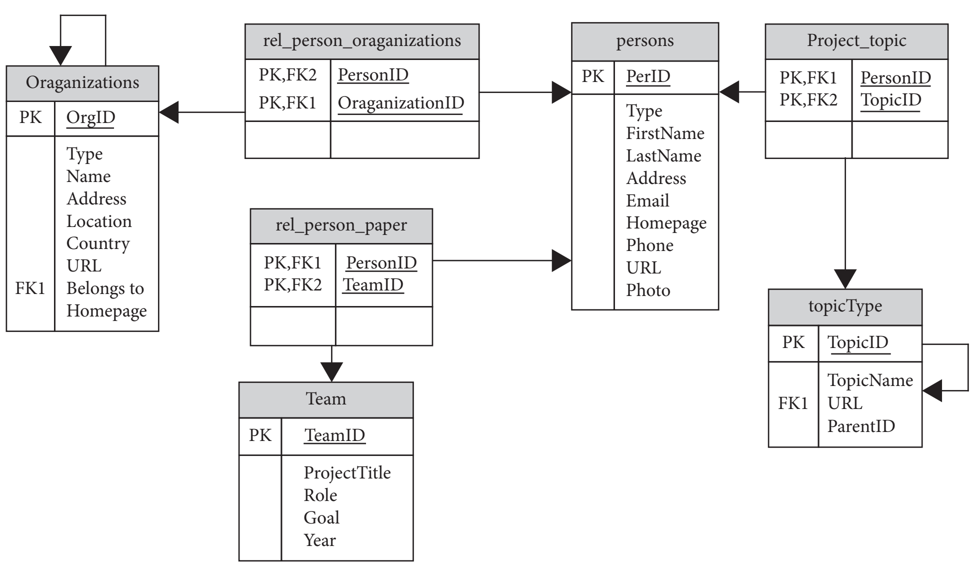

Figure 7: Structure of collaborative innovation platform database of animation project (part).

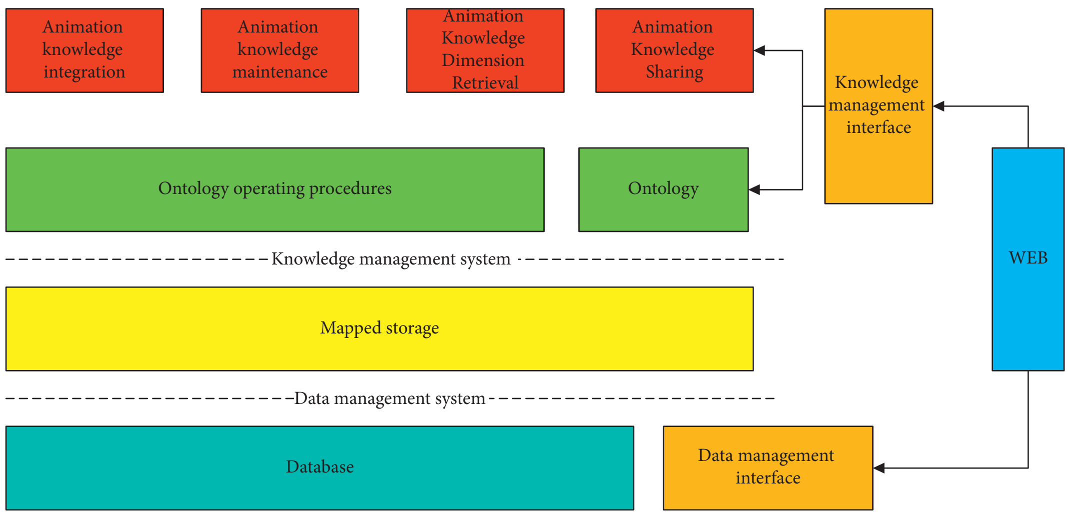

FIGURE 8: Docking of collaborative innovation platform of animation project with the existing data management system.

strengthening extracurricular practice, innovating animation design, training managers, developing characteristic industries, etc., which is an inevitable measure for the development of the animation industry in digital media.

5. Conclusion

Under the trend of economic globalization, competition among industries is becoming more and more fierce, so is the animation industry. Animation industry plays a very important role in the development of China's national economy. Under the background of digital technology, China's animation industry will gradually develop in the directions of science and technology, intelligence, and electronics. As the pioneer of the animation industry, the animation specialty in college needs to integrate a variety of technologies, strengthen extracurricular practice, and innovate in animation design. The collaborative innovation system of animation specialty in colleges under digital technology requires that the curriculum design of animation specialty in colleges and universities should be based on the curriculum design to strengthen the deep cooperation among government, universities, and enterprises. Based on this, the collaborative innovation platform for animation projects is constructed through the integration of technology in animation design and digital media, which can realize the integration, maintenance, retrieval, and sharing of animation knowledge. The application of a collaborative innovation platform can improve the soft environment of an animation project's development, promote the innovation of knowledge, accelerate the development of animation projects, improve the quality of animation works, and stimulate the overall competitiveness of the animation industry, which then effectively advance the region of the animation industry.

Data Availability

The dataset can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Physical Fitness Evaluation of College Students at the Stage of Physical Exercise Behavior Based on Bayesian and Data Mining

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It is difficult for the traditional physical fitness evaluation methods to dig useful information from massive data, and the accuracy of physical fitness evaluation is low. Therefore, this study proposed a physical fitness evaluation method in the stage of physical exercise behavior based on Bayesian and data mining for the college students. The purpose was to set the association rules of exercise behavior stage, to mine the association mapping relationship in the data set by using frequent itemsets, to build a regression model and to select the best physical variables in the exercise behavior stage. The frequent itemset was used to eliminate the redundancy of physical fitness data, the causal relationship was used to sort the physical exercise behavior stage, and the transformation of physical fitness evaluation index system was realized through Bayesian network topology to realize the physical fitness evaluation in the physical exercise behavior stage. The experimental results showed that the accuracy of this method was as high as 97.62%, and the recall rate of fitness data evaluation was as high as 99.3%. At the same time, the effect of fitness evaluation was better in a short evaluation time.

1. Introduction

It is easy to understand the connotation of physical fitness literally. It mainly refers to the quality of the human body. The quality of physical fitness is affected by many factors, among which it is determined by innate inheritance and acquired basis [1]. To judge whether a person's physical fitness is good or bad mainly means that the shape of the body has the development level, the level of physiological function, athletic ability, physical quality development, and psychological development. These five aspects determine people's physical fitness level [2–5]. Relevant scholars put forward the theory of stage change, believing that behavioral change consists of four factors: stage of change, balanced decision, change process, and self-efficacy [4, 5]. By applying the theory to physical exercise behavior, it is concluded that the change of physical exercise behavior goes through five stages, namely, pre-expectation stage, expectation stage, preparation stage, action stage, and maintenance stage. According to the different behavioral stages of the college students' physical exercise, a comparative research was made to prove that the physical exercise assessment put forward by this study was effective.

Cheng and Wang built a physical health policy attitude assessment model to carry on an empirical analysis on physical health policy, policy satisfaction, the relations between and among policy behavior, and attitude toward policy model by applying the method of structural equation model. The method made an effective evaluation of the physical state. The accuracy was high, but the efficiency was poor [8]. He et al. designed a kind of Chinese urban adolescent physical fitness environmental assessment method [9], the application of standard index quantitative and qualitative screening based on the Delphi method, and analytic hierarchy process was used to index weight assignment. This method could improve the physical environment qualitative measurement accuracy and the content, but the poor efficiency of environmental assessment was low.

Hu et al. proposed the physique classification and evaluation method based on k-medoids method [10] and conducted psychological tests on the students, extracting psychological factors by principal component analysis and evaluating the physique state by a three-level fuzzy evaluation model. This method could reasonably classify the physique, but the efficiency of physique health classification and evaluation of the college students was not satisfactory. Zhang and Yun put forward the body posture evaluation method of the students through big data developed a set of scientific and reasonable body posture evaluation system to help the schools, teachers, and students understand their body posture and health status correctly through big data, scientifically and to guide the schools and teachers to formulate curriculum contents conducive to the students' physical and mental development and effectively evaluated their body posture. However, the evaluation accuracy was low [11].

In the modern society, with the highly developed information, the traditional statistical methods are difficult to find useful information from massive data. Data mining has become an important means of knowledge discovery based on big data. Therefore, this study proposed a physical fitness evaluation method at the stage of physical exercise behavior based on Bayesian and data mining. The specific research ideas were as follows:

Firstly, association rules of exercise behavior stage were set, association mapping relationship of data set was mined by frequent itemsets, and regression model was constructed.

Secondly, the best physical fitness variable in exercise behavior stage was chosen. Frequent itemsets were used to eliminate the redundancy of physical fitness data, and causality was used to rank the stages of physical exercise behavior.

Next, the physical fitness evaluation index system was transformed by Bayesian network topology to realize physical fitness evaluation at the stage of physical exercise behavior.

Finally, through the accuracy and efficiency of physical fitness assessment, the effectiveness of this method in physical fitness assessment of college students at the stage of physical exercise behavior was verified and a conclusion was drawn.

2. Data Mining of Physical Fitness of College Students at the Stage of Physical Exercise Behavior

2.1. Association Rules in Data Mining of College Students' Physical Fitness Data. Each test object determined a unique identification (TID), then each TID contained the following information: physical exercise behavior stage (field 1), gender (field 1), and physical fitness test index (field 11). The height and weight in the test index derive BMI, BMI = weight (kg)/height (M) 2, VO2max, and vital capacity were divided into weight composition (relative VO2max and relative vital capacity) respectively to form database D. Clementine12.0 data mining software requires type consistency and dimensionless processing of the data of input variables and output variables when modeling [12]. The type of input field of association rule data mining was generally required to be number, which could realize the digitization of physical fitness test data according to the national physical fitness measurement standard, that is, the test results could be scored as 5, 4, 3, 2, and 1 according to their advantages and disadvantages. In association rule data mining, the type of output field required to be set was character type (string), which meant that the output field "physical exercise behavior" was divided into five types as follows: pre-expectation stage, expectation stage, preparation stage, action stage, and maintenance stage. Association rule data mining was to find the minimum support min specified by the user in the transaction database D_ Sup and min_ All association rules of conf [13]. Set min as required_ Sup, "individual index score of physical fitness test" was taken as the input field and set min_ Conf, establishing the "association mining rules between physical exercise behavior and single indicators" model to explore the impact of physical exercise behavior on physical fitness and providing decision support for the college students' physical health with different physical exercise behaviors.

Since there were collinearity problems in the college students' physical health indicators, such as body weight and vital capacity, the principal component regression analysis was adopted. Principal component regression analysis transformed a group of multiple related data into a group of linearly unrelated variables through orthogonal changes, and the transformed group of variables was called the main component [14]. The main method of principal component analysis was F1 (the first comprehensive index), that is, the greater the variance of F1, the more information it contained. Therefore, the variance of the first comprehensive index selected in all linear combinations became greater. If the information contained in the first index selected was not enough to include all indexes, F2 shall be included on the basis of the first index until it was accepted. The input indicators could represent the information of all the original indicators [15]. The second stage was to construct a regression model from the principal components included. The constructed regression model was of great significance for the screening of regression variables. In a word, the principal component regression model could use a set of fewer variables to obtain the selection of the best variables [16]. The specific process was as follows:

Since each index was different in units, the value was also different, so the data must be standardized, and the processing method adopted Z change:

$$X_i = \frac{x_2 - x_1}{\gamma}. \tag{1}$$

In formula (1), x_1 and x_2, respectively, represent the physical health data of the college students were measured twice, γ represents the number of indicators, and n represents the standardized function of data. For principal component suitability test, such as Bartlet Test statistics and KMO test, if the p value obtained by Bartlet Test was less

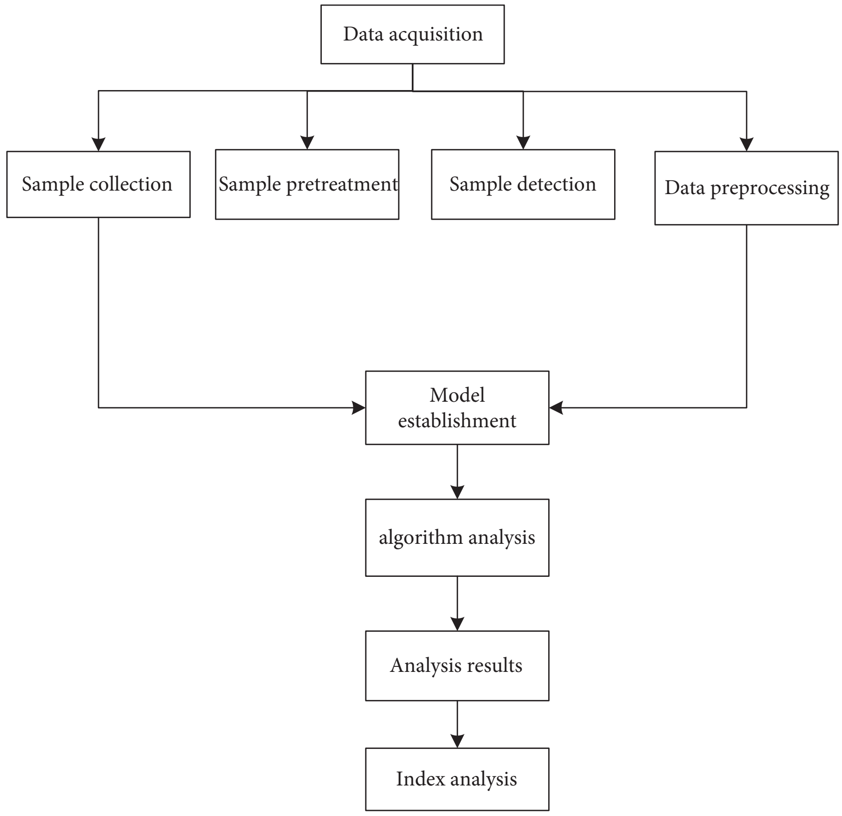

FIGURE 1: Data mining route of physical fitness of college students in physical exercise stage.

than 0.05 or the value of KMO test was greater than 0.5, the principal component analysis could be performed.

The correlation coefficient matrix between each index was calculated, and the correlation formula is as follows:

$$r_{ij} = \frac{1}{n}\sum_{i=1}^{k} x_{ikx_{jk}}. \tag{2}$$

The matrix of correlation coefficient was changed by R to make its variance reach the maximum value, and on this basis, the eigenvalue of R and I and their corresponding eigenvector were obtained.

The principal component formula was constructed according to the component coefficient matrix. It should be noted that the variables in the constructed expression were not original variables but standardized variables.

The construction of principal component regression equation required it to take the extracted principal components as independent variables and physical fitness score as dependent variables to establish a principal component regression model and select meaningful factors [17].

2.2. Redundancy Elimination of College Students' Physical Fitness Data Based on Frequent Itemsets. The process of physique data mining in the college students' physical exercise stage is shown in Figure 1.

Frequent Itemsets with support were greater than the minimum support threshold. The enumeration method could be used to enumerate all possible K itemsets, and then

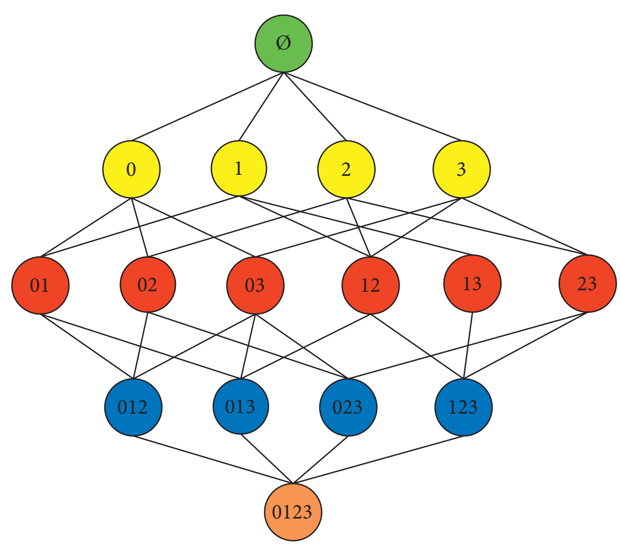

FIGURE 2: Frequent itemsets.

calculate the support of each itemset. A dataset with items could produce a set of items, and a set of items that met the support threshold could be small [18]. Obviously, enumeration was not an effective method when the data set was large. The frequent itemset enumeration lookup process was shown in Figure 2. As seen from Figure 2, there were altogether 15 data sets with 4 data sets.

In order to improve the efficiency of finding Frequent Itemsets, itemsets that were unlikely to reach the support

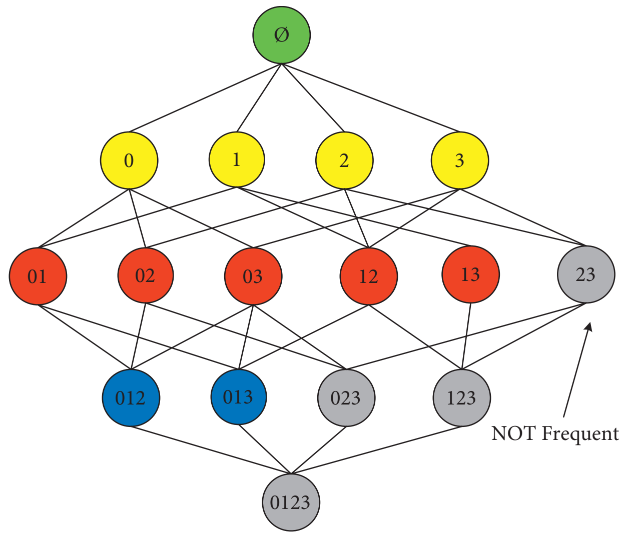

Figure 3: Frequent itemset data redundancy elimination.

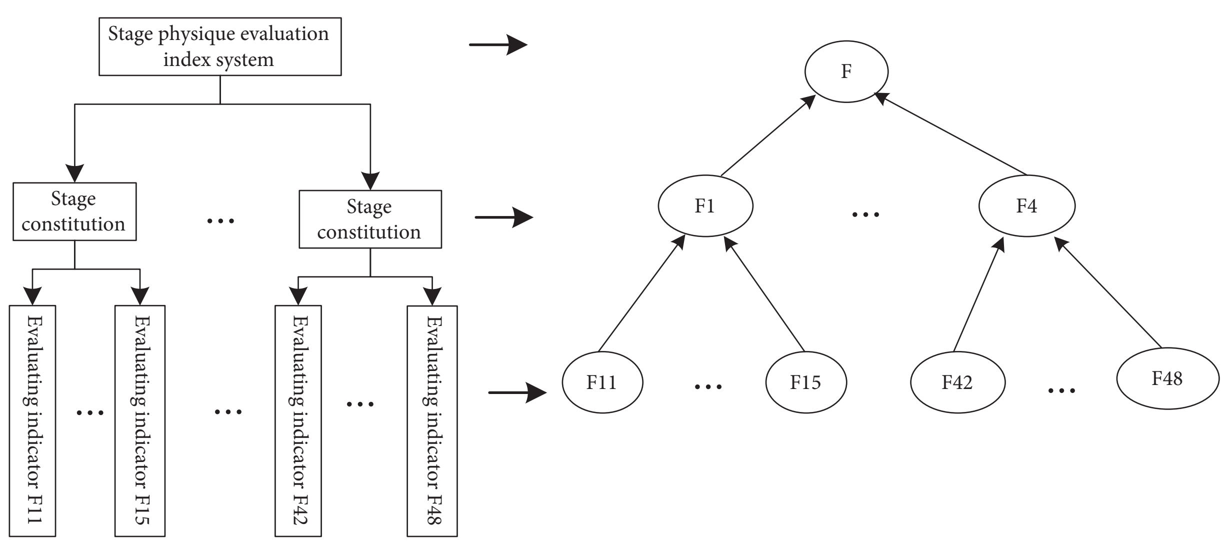

Figure 4: Initial topology of Bayesian network.

threshold were deleted. If the itemset was frequent, its subset must also appear frequently. Conversely, if a child itemset was infrequent, its parent set was not a frequent itemset. The redundancy elimination of frequent itemset data is shown in Figure 3, and the shaded itemset in the figure indicates that it is cropped out [19].

2.3. Physical Fitness Evaluation of College Students at the Stage of Physical Exercise Behavior Based on Bayes Theorem. Bayes theorem is a theorem for calculating conditional probability proposed by Bayes in the 18th century [20]. The main contents of the theorem include assuming that a complete event contains n mutually exclusive events, each mutually exclusive event is represented by $H_1, H_2, \ldots, H_n$ and its probability is $\mathrm{P}(H_i), i = 1, 2, \ldots, n$. It is found that event a occurs randomly with each mutually exclusive event, and when the conditional probability of event A when each mutually exclusive event occurs is known, that is $\mathrm{P}(A \mid H_i)$, then the probability of $\mathrm{P}(H_i \mid A)$ is as follows:

$$\mathrm{P}(H_i \mid A) = \frac{\mathrm{P}(H_i)\mathrm{P}(A \mid H_i)}{\sum_{j=1}^{n} \mathrm{P}(H_j)\mathrm{P}(A \mid H_j)}. \tag{3}$$

Bayesian network (BN) is also called causal probability network and reliability network. The core of this method is to construct the Bayesian network topology between variables based on causal relationship and analyze the occurrence probability of variables through structure learning, parameter learning, and reasoning analysis. The Bayesian network topology learning method based on the ranking principle of causality and the principle of reason pointing to result is adopted to make the constructed Bayesian network topology clear [21–23]. The transformation of physical fitness evaluation index system of college students in physical exercise stage is realized through the initial topology of Bayesian network, as shown in Figure 4.

Through the transformation of the index system, the Bayesian network topology lacks the causality between the evaluation indexes. In order to increase the causality between the indexes in the network topology and make the network structure more reasonable, this study adopted the social network analysis method to optimize the structure.

The Bayesian network topology was transformed through the index system, which lacked the causal relationship between evaluation indexes. In order to increase the causal relationship between indexes in the network topology and make the network structure more reasonable, the logical reasoning method was used to identify the causal relationship between nodes. Based on the Bayesian network topology, the key risk factors and key risk relationships in the social network were analyzed, and the middle centrality of points was used for physical fitness evaluation [24]. The greater the middle centrality of the node, the stronger its physique evaluation ability was. Its calculation formula is as follows [25–27]:

$$S_r = \sum_{j}^{n} \sum_{k}^{k} O_{jk}(r), \tag{4}$$

where $j \neq k \neq r$ and $j < k$, and $O_{jk}(r)$ represents the ability of point r to control the communication between point j and point k. Assuming that there were W_{jk} lines in the path between point j and point k, and $W_{jk}(r)$ lines passing through point r in the path, then

$$O_{jk}(r) = \frac{W_{jk}(r)}{W_{jk}}. \tag{5}$$

The middle centrality theory of line referred to the degree to which the relationship between two nodes in the network structure was located at the center of the whole social network structure [28]. The greater the middle centrality of the line between two nodes, the stronger the risk transmission capacity was. The calculation formula is as follows:

$$S_{x\longrightarrow y} = \sum_{j}^{n} \sum_{k}^{k} O_{jk}(x \longrightarrow y), \tag{6}$$

where $j \neq x \neq y \neq k \neq r$ and $j < k$, and $O_{jk}(x \longrightarrow y)$ represents the ability of relationship $x \longrightarrow y$ to control the communication between point j and point k [29]. Assuming that there were W_{jk} bars in the path between point j and point k, and $W_{jk}(x \longrightarrow y)$ bars in the path passing through the relationship $x \longrightarrow y$, then

$$O_{jk}(x \longrightarrow y) = \frac{W_{jk}(x \longrightarrow y)}{W_{jk}}. \tag{7}$$

On the above constraints, n experts in relevant fields were invited to judge the occurrence probability of the risk level of the node. The nth expert judged the probability of the risk level i, $i = \{1, 2\}$ of the node A_t, B_t, $t = \{0, 1, 2\}$ according to the seven-level language variables, transformed it according to the corresponding relationship, and calculated the triangular fuzzy probability PTI, n of the evaluation index with the transformed triangular fuzzy number.

$$P_{ti,n} = \left(x_{ti,n}, y_{ti,n}, z_{ti,n}\right). \tag{8}$$

The obtained triangular fuzzy probability was averaged. Averaging was the arithmetic average of the evaluation results of experts, which aimed to rationalize the final probability value [30]:

$$P_{ti,FAM} = \frac{P_{ti,1} \oplus P_{ti,2} \oplus \cdots \oplus P_{ti,n}}{n} = \left(x_{ti}, y_{ti}, z_{ti}\right). \tag{9}$$

The mean triangular fuzzy probability was defuzzified and calculated by the face value mean method:

$$P_{ti,AM} = \frac{x_{ti} + 2y_{ti} + z_{ti}}{4} \tag{10}$$

Normalize the probability value so that the sum of the final probability value was 1:

$$P_{ti} = \frac{P_{ti,AM}}{\sum_{i=0}^{2} P_{ti,AM}}. \tag{11}$$

According to the calculated root node prior probability distribution and child node conditional probability distribution and with the help of GENIE 2.3 software, the physical parameters of the college students in the stage of physical exercise were studied. Then to carry out the initial assignment to each node, the calculated probability value was imported according to the triangular fuzzy number, the subnode probability was calculated with the maximum likelihood estimation method built in the software, and finally, the probability value of each node was obtained, so as to realize the physical exercise behavior stage.

3. Experiment

3.1. Experimental Design. Determining the evaluation index was important in the comprehensive evaluation of college students' health. The intelligent health promotion service system focused on the internal functions of the body and used intelligent instruments to directly measure individual vital capacity, body composition, and cardiovascular and balance ability, including height, weight, vital capacity, and balance ability. The specific forms of physical exercise for the college students included running, core strength training, and vital capacity.

According to the *National Student Physical Health Standard* (2014), physical fitness test was conducted for 3969 students. The test indicators included height, weight, 50 m running, vital capacity, standing long jump, and sitting posture forward flexion. In addition, male students needed to measure 1000 m running and one-minute pull up, while female students needed to measure 800 m running and one-minute sit-ups. The BMI of the college students was divided into four grades: 17.2 (female)/17.9 (male)~23.9 is normal, ≤17.1 (female)/17.8 (male) is low weight, 24.0~27.9 is overweight, and ≥28 is obesity. SPSS17.0 and R language 3.4.4 software were used to analyze age, height, weight, and physical health indicators, including 50 m running, vital capacity, standing long jump, sitting body flexion and

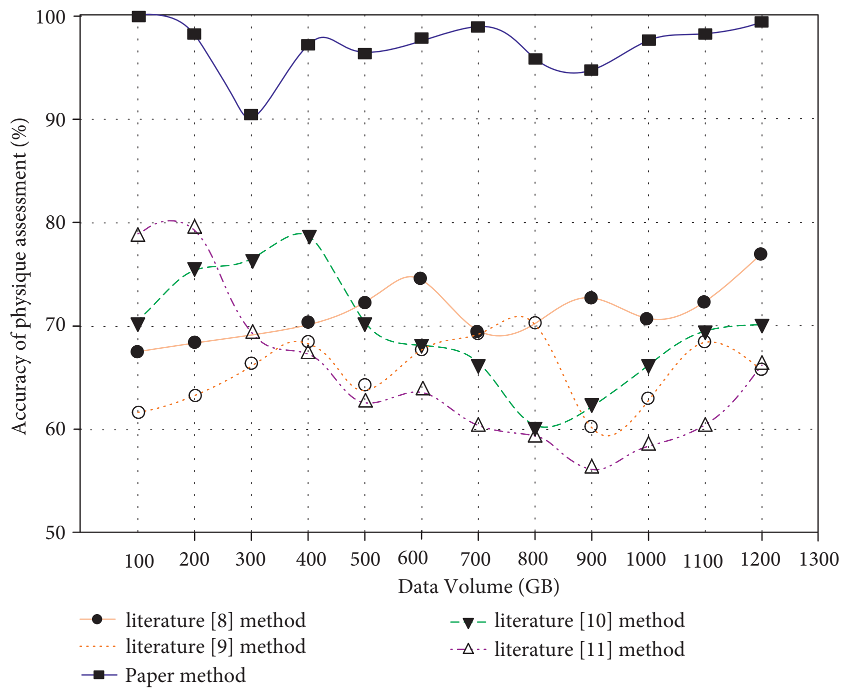

FIGURE 5: Accuracy of physical fitness assessment under different methods.

1000 m running (male), pull-up (male), 800 meters running (female), and sit-ups (female). The original data of 3969 students were carefully reviewed to delete the missing value data and retain the data of 3960 students. According to the needs of data mining, a physical database was created in the form of Excel 2010 according to gender, height, weight, and vital capacity, including sitting and lying precursor, standing long jump, sit-ups, pull up, 50 m running, and endurance (1000 m or 800 m). The original data were processed according to the standard.

3.2. Training Sample Preprocessing. For N samples $1, 2, \ldots, n$, there were p indicators $x_1, x_2, \ldots, x_p$. x_{ij} to represent the i-th physical fitness data and the j index result to obtain the physical fitness data matrix:

$$\begin{bmatrix} X_{11} & \ldots & X_{1p} \\ \ldots & \ldots & \ldots \\ X_{n1} & \ldots & X_{np} \end{bmatrix}. \tag{12}$$

Then, the mean and standard deviation were respectively expressed as follows:

$$X_{n1} = \frac{1}{n}\sum_{i=1}^{n} x_{ij},$$
$$S_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \overline{x_j}\right)^2}. \tag{13}$$

After standardization, the new data was

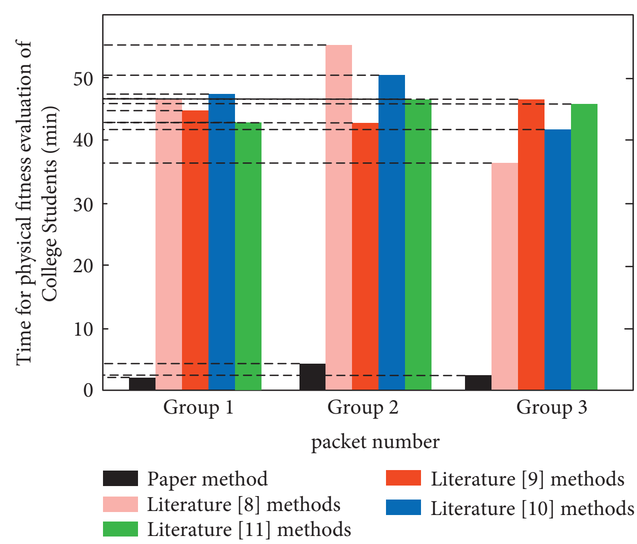

FIGURE 6: Time for the physical fitness assessment.

$$x'_{ij} = \begin{cases} \dfrac{x_{ij} - \overline{x_j}}{S_j}, & S_j \neq 0, \\ 0, & S_j = 0, \end{cases} \quad (i = 1, 2, \ldots, n\ j = 1, 2, \ldots, p). \tag{14}$$

Experimental verification was carried out according to the new standardized data results.

3.3. Experimental Result

3.3.1. Accuracy of Physical Fitness Assessment. In order to verify the effect of this method on physical fitness evaluation,

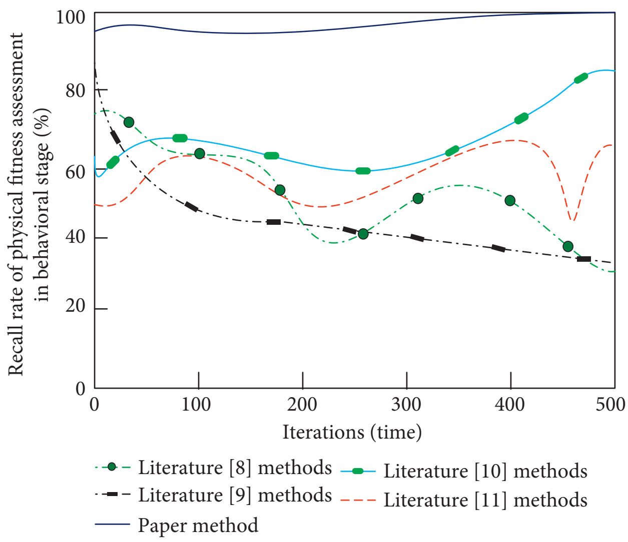

Figure 7: Recall rate of physical fitness data evaluation.

the methods of literature [8], literature [9], literature [10,] and literature [11] were compared with this method, and the evaluation accuracy results were shown in Figure 5.

It could be seen from the analysis of Figure 6 that when the data volume was 100 GB, the accuracy of physique assessment of literature [8] method was 67.42%, that of literature [9] method was 61.56%, that of literature [10] method was 70.23%, that of literature [11] method was 78.67%, and that of this method was 99.88%; When the data volume was 500 GB, the evaluation accuracy of literature [8] method was 72.15%, that of literature [9] method was 64.21%, that of literature [10] method was 70.27%, that of literature [11] method was 62.52%, and that of this method was 96.32%. When the data volume was 1000 GB, the evaluation accuracy of literature [8] method was 70.61%, that of literature [9] method was 62.88%, that of literature [10] method was 66.29%, that of literature [11] method was 58.37%, and that of this method was 97.62%, which proved the effectiveness of this method. This was because the method in this study adopted causality to rank the stages of physical exercise behavior and realized the transformation of physical evaluation index system through the Bayesian network topology structure, so that the accuracy of physical evaluation was greatly improved.

3.3.2. Physical Fitness Assessment Time. In order to verify the evaluation efficiency of this method, the methods of literature [8], literature [9], literature [10], and literature [11] are compared with this method, and the evaluation time results are shown in Figure 6.

By analyzing Figure 6, it could be seen that there were differences in evaluation time under different methods. For group 1, the evaluation time of literature [8] method was 47.5 min, that of literature [9] method was 45.0 min, that of literature [10] method was 48.2 min, that of literature [11] method was 43.6 min, and that of this method was 3.2 min. For group 3, the evaluation time of literature [8] method was 36.9 min, that of literature [9] method was 47.5 min, that of literature [10] method was 40.8 min, that of literature [11] method was 47.0 min, and that of this method was 3.7 min; On the whole, in the above three groups of experiments, the time of physique evaluation by this method was no more than 5 min, which showed that the physique evaluation efficiency of this method was high due to the optimal variables of physical fitness in the exercise behavior stage were selected, the redundancy of physical fitness data was eliminated by frequent itemsets, and the causal relationship was used to rank the stages of physical exercise behavior, so as to shorten the evaluation time of the method.

3.3.3. Evaluation Result Recall Rate. In order to verify the evaluation recall rate of this method, literature [8], literature [9], literature [10], and literature [11] were compared with this method, and the evaluation recall rate results were shown in Figure 7.

Figure 7 revealed that the recall rate was different under different methods. When the number of experimental iterations was 100, the data evaluation recall rate of literature [8] method was 64.5%, the evaluation recall rate of literature [9] method was 57.2%, the evaluation recall rate of literature [10] method was 70.6%, the evaluation recall rate of literature [11] method was 63.9%, and the evaluation recall rate of this method was 98.2%; When the number of experimental iterations was 300, the evaluation recall rate of physical data of literature [8] method was 50.8%, that of literature [9] method was 42.1%, that of literature [10] method was 67.5%, that of literature [11] method was 60.2%, and that of this method was 99.3%; The evaluation recall rate of this method was significantly higher than that of other methods, indicating that this method had a higher effect on physical fitness evaluation. This was because this study used frequent itemsets to mine the association mapping relationship in the data set and constructed the regression model and frequent itemsets could effectively improve the effect of physical fitness assessment by eliminating the redundancy of physical fitness data.

4. Conclusion

This study introduced a physical fitness evaluation method for the college students at the stage of physical exercise behavior based on Bayesian and data mining. The frequent itemset was used to mine the association mapping relationship in the data set to obtain the selection of the best physical variables. The data redundancy of the frequent itemset was used to eliminate, the causal relationship was used to sort the exercise behavior stage, the transformation of the physical evaluation index system in the physical exercise stage was realized through the initial topology of Bayesian network, and the physical evaluation in the physical exercise behavior stage was realized. The experimental results showed that

(1) When the data volume was 1000 GB, the accuracy of physical fitness evaluation in the physical exercise behavior stage of this method was 97.62%, which proved the effectiveness of this method.

(2) This method took less than 5 minutes to evaluate the physique in the stage of physical exercise behavior, which showed that the physique evaluation efficiency of this method was high.

(3) When the number of experimental iterations was 300, the recall rate of fitness data evaluation in the physical exercise behavior stage of this method was 99.3%, which showed that the evaluation effect of this method was high.

However, even though some progress in the physical exercise behavior stage of physical fitness assessment was made, it needed to be further improved.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analysis of Lifeboat Embarkation Efficiency for Cruise Passengers under Multiple Scenarios

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Lifeboats are important equipment to ensure the safety of passengers when a serious accident occurs in the ship. Higher efficiency of lifeboat embarkation is beneficial to improving passenger survival. This study divides lifeboat embarkation into queuing and seat selection stages and studies the embarkation process of cruise passengers. According to the characteristics of two stages of the embarkation process, transfer rules of queue and activity rules of the passenger are proposed. Combined with the rules, 16 types of embarkation simulation scenarios are established. The simulation results show that the embarkation efficiency of the group passenger is lower than that of the individual passenger. When passengers select seats from outboard row to inboard row, the speed of embarkation is faster than that of random seating selection. Compared with only considering the queue length, the embarkation is more efficient if passengers also consider the seat availability of lifeboats when they transfer between queues. The analysis of the results proves that the embarkation efficiency can be improved through proper guidance on the behavior of passengers in queuing and seat selection.

1. Introduction

Maritime lifesaving is one of the important concerns for the operation of the cruise ship. If the ship cannot maintain its normal condition in case of a serious accident occurs, passengers need to abandon the ship through lifeboats. The embarkation station is usually located on one deck of the cruise ship, and all passengers need to embark on the lifeboat from the station. However, passenger panic will have a negative impact on the embarkation process in an emergency. Compared with ordinary passenger ships, cruise ships carry a large number of passengers. In order to ensure passenger safety, the highly effective organization of the embarkation process is essential.

For the safety of the ship passengers, some scholars have conducted research on the maritime lifesaving system. The lifesaving system of the ship is an integral part of emergency equipment in the process of abandoning the ship [1]. Divkovic and Dahlrot [2] introduced requirements in the process of lifeboat embarkation and launching based on IMO's (International Maritime Organization) *International Life-Saving Appliance (LSA) Code* [3]. They recruited 25 volunteers to participate in the lifeboat embarkation experiment and carried out the experiment for the lifeboat embarkation process of the cargo ship. It took three minutes and 52 seconds for all volunteers to embark on the lifeboat, which is 52 seconds longer than the three minutes required by LSA Code.

The safety, reliability, and other factors of lifeboat systems are very important to the safety of passengers. Abramowicz-Gerigk and Burciu [4] took the evacuation of offshore platforms as the research object, and they introduced the general evaluation method for marine lifesaving systems and selected liferafts as an example to conduct safety evaluation. In addition, the lifeboat system will also impact by other factors such as the matching degree between the lifeboat capacity and the number of assembled passengers [5], the human error in the operation of the lifeboat system [6], and the evacuation behavior of passengers [7]. Conversely, the process of embarkation and launching the lifeboat will also have a negative impact on the health of passengers [8]. The positions of objects or persons in the space could be collected by using wireless sensors or Internet of things devices [9–12]. Based on the existing lifeboat system, Andreadakis et al. [13] explored the possibility of establishing a wireless system for detecting the safety of passengers. Passengers wear bracelets with near-field communication or radio-frequency identification, and bracelets would record the relevant data through card readers when passengers embarked on lifeboats. Then, the system could allow the crew to obtain accurate evacuation statistics in real time.

When passengers arrive at embarkation stations, they will generally queue up to embark lifeboats under the organization of staff or by self-organization. Some scholars have studied the behavior of pedestrians in the queuing process. The service efficiency of the queue is usually affected by the organization of the queue, and the customer waiting time could be reduced by reasonable redistribution and management of the queue [14]. The pedestrian flow through services is also related to the number of servicers and service points [15]. In addition, the width, type, and the bottleneck in the path will have an impact on the movement of the pedestrian queue. Zhang et al. [16] analyzed the relationship between the bottleneck and pedestrian queuing characteristics through experiments. Köster and Zönnchen [17] added a loosely queuing model to the pedestrian flow model to simulate the movement behavior of pedestrians at the place of evacuation bottleneck. Zhuang et al. [18, 19] proposed an agent-based cellular automaton to study the aggregation of pedestrian flow at the bottleneck and the impact of self-organizing queue behavior on pedestrian movement efficiency.

The behavior of pedestrians has an impact on the queuing process, and some evacuation models are used to simulate queuing behavior. The cellular automata model as one of the evacuation models can be used to analyze the interaction between pedestrians. This model had been used to simulate the queuing behavior of pedestrians at the server window in the canteen [20, 21] and queuing behavior of students who evacuate from the classroom [22, 23]. Wu and Guo [24] constructed a microscopic pedestrian model with the potential field that can drive the movement of pedestrians. In the model, pedestrians can intersect with others at different angles, and they explored the impact of the intersection angle between passing pedestrians and queuing pedestrians on pedestrian movement efficiency. In another study, Zheng et al. [25] proposed a new concept of the queuing line, which divides the queuing process into walking and queue selection stages. Based on the social force model and queuing theory, they developed two microsimulation models to simulate these two stages. In considering the effect of walking distance [26] and volume [27] of the pedestrian in the queuing process, Yanagisawa et al. established the pedestrian queuing system [28] combined the queuing theory with the microspatial discrete model in pedestrian dynamics. Taking service windows as objects [29], they studied the influence of pedestrian tendencies, windows locations, queue length on pedestrian transit time, and entrance blocking rate.

Family and friends often travel together on the cruise tour. They usually will spontaneously form groups, which have a relevant influence on the crowd dynamics behavior, and groups usually tend to act together [30]. Pan et al. [31] discussed the influence of small group behavior on evacuation and established a multi-agent evacuation model. By changing the type of groups and widths of passage, they simulated unidirectional and bidirectional evacuation processes. Nguyen et al. [32] built two models that contained random and logistic regression models, and they combined the controlled behavior experiment of fire evacuation to simulate the process of individual and group evacuations.

There is a correlation between the group size and the walking speed of the group. The mean walking speed of the group decreased with the increase of the group size [33], but the total evacuation time would decrease when the number of the group increased [34]. The evacuation efficiency of groups with self-organized queues at the exit was higher than that without queues [35]. In the process of group evacuation, individual members would reunite with the group after separating [36]. If the group is made up of family members, the mutual assistance between family members would have a negative impact on the evacuation process [37]. Moreover, the emotions of pedestrians will have a certain impact on evacuation efficiency. The emotions would spread between group members [38], and the propagation of emotion could improve crowds' cognition of danger and increase the survival rate of pedestrians [39]. If the evacuation is guided by a group leader, the evacuation efficiency of the group would also be improved [40].

The embarkation process of lifeboats has its special characteristics: first, unlike ordinary queuing problems, the capacity of the lifeboat is limited, and it is also difficult for passengers outside the lifeboat to obtain internal information. Once the number of entered passengers is about to reach the capacity of the lifeboat, it has a negative effect on the embarkation efficiency if there are many passengers waiting outside the lifeboat. Second, group passengers tend to choose the same queue or enter the same lifeboat, and the embarkation process may be affected by group behavior. Finally, the space inside the lifeboat is extremely tight. The average area for each passenger is less than 0.3 m^2, and the space between seats is also used as the passage. If passengers who enter the earlier take seats near the door or inboard place, it will hinder the movement of subsequent passengers who would enter the lifeboat. At present, there are few studies on the embarkation efficiency of lifeboats by considering the behavior of passengers inside and outside the lifeboat. There are multiple lifeboats arranged on the cruise ship, and the rational embarkation process is particularly important for improving the efficiency of passengers.

The main contributions of this study are as follows: first, according to the embarkation characteristics of lifeboats, we divide the embarkation process into the queuing process outside the lifeboat and the seat selection process inside the boat. Second, depending on the behavior characteristics of passengers under self-organization or organization by staff, transfer rules between queues and activity rules of passengers are proposed. Third, the influence of rules on passenger embarkation efficiency is analyzed, and the feasibility of improving passenger embarkation efficiency through rational rules is confirmed.

The other parts of this study are as follows: Section 2 provides the description of the research problem. The simulation model of embarkation is constructed in Section 3. In Section 4, simulation results are analyzed. The last section presents the conclusions and future works.

2. Description of the Research Problem

The embarkation and launching of the lifeboat are the final steps for passengers to abandon the ship. When passengers arrive at the embarkation station, they can embark on lifeboats under the guidance of the staff or by action themselves. To simulate the embarkation process, the embarkation model of the lifeboat and queue is established. The research object is a medium cruise ship with three lifeboats on each side of the embarkation deck. Figure 1 shows the embarkation area on the portside. Lifeboats 1 and 3 are double-deck lifeboats, and the capacity of these two lifeboats is 305 persons. Lifeboat 2 is a single deck, and its capacity is 146 persons.

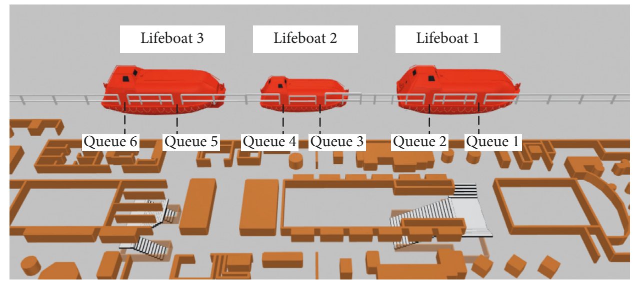


Figure 1: The embarkation area of lifeboats.

2.1. Queuing Model of Lifeboats. Queuing theory is mostly used to model pedestrians arriving at a service facility in a certain way. When pedestrians arrive at the service point, they stand in line and wait until their turn to be served. Once passengers have received service, they are usually assumed to have left the system. Queues models are mainly divided into M/M/C and M/M/1. In M/M/C model, pedestrians are placed in one queue, and pedestrians can receive services from multiple service points. In this queuing mode, pedestrians can only move in an orderly way, and the mobility of pedestrians is limited. This model is widely used in airport check in. In M/M/1 model, multiple queues are arranged in parallel, and each queue corresponds to a service point. This queuing can play the role of dispersing pedestrians. There are multiple queues for pedestrians to select, and some pedestrians may transfer between queues to choose the shortest queue.

The lifeboat embarkation model can be divided into two stages: the first stage is the passengers preparing to enter the lifeboat through the queue, and the second stage is the passengers selecting seats after they enter the lifeboat. The first stage of embarkation is similar to the queuing process. When passengers arrive at the embarkation area, they will form a queue to wait for the embarkation under the organization of staff or by self-organization. In the process of embarkation, the entrance of lifeboats can be considered as the service point, and passengers can be regarded as having received the queue service as long as they enter the lifeboats. According to the characteristics of lifeboat embarkation, the M/M/1 model is selected to simulate the embarkation process of passengers in this study. Each lifeboat has two entrances, and a queue is distributed in front of each entrance. Locations of queues are shown in Figure 1. In the initial stage, passengers are assumed distributed in the embarkation area and already wear life jackets. Passengers would move to the nearest lifeboat and form queues at the entrances of lifeboats.

2.2. Types of Embarkation Scenarios. As the capacity of the lifeboat is limited, passengers need to change queues when the lifeboat is full. Passengers generally prefer shorter queues since that can make them enter the lifeboat more quickly, which means that passengers may select the shorter queues by transferring between queues. Families or friends are traveling together on cruise ships, and they usually act in a group. The group passengers tend to preferentially select the same queue or enter the same lifeboat, while individual passengers will directly choose the nearest or shortest queue. Therefore, the transfer behavior can also be divided into transfers between queues of the same lifeboat or queues of all lifeboats. It is often difficult for passengers outside the lifeboat to verify the number of the remaining seats left inside the lifeboat. Hence, it is not beneficial to embark as there are many passengers waiting outside the lifeboat when the capacity of the lifeboat is nearly full. If passengers are under the guidance of the staff, these passengers could transfer among queues by considering the remaining seats of lifeboats.

Once entering the lifeboat, passengers may select seats at random. However, random seating selection may hinder the entry of subsequent passengers because of the narrow interior space of lifeboats. If passengers inside the lifeboat select seats from outboard row to inboard row under the guidance of the staff, then the passenger outside the lifeboat can enter the lifeboat smoothly.

Based on the above analysis, transfer rules of passengers between queues can be divided into four types: transfer between queues of all lifeboats (TAL), transfer between queues that belong to the same lifeboat (TSL), transfer between queues of all lifeboats based on the seat availability of lifeboats (TALSA), and transfer between queues that belong to the same lifeboat based on the seat availability of lifeboats (TSLSA). Activity rules of passenger can be divided into four types: the individual passenger selects seats from outboard row to inboard row (ISSOI), the individual

Table 1: Simulation scenarios of lifeboat embarkation.

		Activity rules			
		IRSS	ISSOI	GRSS	GSSOI
Transfer rules	TSL	TSL-IRSS	TSL-ISSOI	TSL-GRSS	TSL-GSSOI
	TAL	TAL-IRSS	TAL-ISSOI	TAL-GRSS	TAL-GSSOI
	TSLSA	TSLSA-IRSS	TSLSA-ISSOI	TSLSA-GRSS	TSLSA-GSSOI
	TALSA	TALSA-IRSS	TALSA-ISSOI	TALSA-GRSS	TALSA-GSSOI

passenger randomly selects seats (IRSS), the group passenger selects seats from outboard row to inboard row (GSSOI), and the group passenger randomly selects seats (GRSS).

The embarkation process is affected by the behavior of passengers, and the characteristic of the behavior of passengers under different rules is disparate. In addition, in order to analyze the difference between individual and group embarkation efficiency, different scenarios are needed to set for individual and group actions, respectively. Therefore, 16 types of embarkation simulation scenarios can be constructed by combining transfer rules and activity rules, as listed in Table 1. Each transfer rule contains four subscenarios. The influence of compound rules corresponding to each scenario on embarkation efficiency will be studied. The cabins on cruise ships are generally standard double rooms, and it is common for two people to travel together. Therefore, one group of passengers is composed of two people in this study.

2.3. Parameters of the Embarkation Model

2.3.1. Total Embarkation Time. For the lifeboat embarkation, the embarkation time is the most important index to measure the embarkation process. The total embarkation time includes the time for passengers to arrive at the queue, the waiting time in the queue, and the time for selecting seats in the lifeboat. The total embarkation time under one scenario can be defined as the time when the last passenger completes the embarkation process, as shown in the following equation:

$$T_{S(i)} = \max\left\{t_{S(i)}^{Pax(1)}, t_{S(i)}^{Pax(2)}, t_{S(i)}^{Pax(3)}, \ldots, t_{S(i)}^{Pax(j)}, \ldots, t_{S(i)}^{Pax\left(N_{Pax}\right)}\right\}, \tag{1}$$

where $S(i)$ represents the scenario i. N_{Pax} represents the total number of passengers. $t_{S(i)}^{Pax(j)}$ is the completion time of embarkation of the j th passenger in scenario i. $T_{S(i)}$ is the total embarkation time when all passengers complete the embarkation in scenario i.

2.3.2. Distribution of Numbers of Embarked Passengers within Time Intervals. Since passengers enter lifeboats through different queues, the completion time of embarkation is distributed discretely. In order to analyze the trend of the completion time of embarkation, the total embarkation time is divided into several time intervals, and the distribution of the number of embarked passengers within each interval is counted, as shown in the following equation:

$$NPA_{S(i)} = \left\{\sum_{l=0}^{6} PA_{S(i)}^{D(1)}(Q(l)), \sum_{l=0}^{6} PA_{S(i)}^{D(2)}(Q(l)), \ldots, \sum_{l=0}^{6} PA_{S(i)}^{D(k)}(Q(l)), \ldots, \sum_{l=0}^{6} PA_{S(i)}^{D\left(N_D\right)}(Q(l))\right\}, \tag{2}$$

where $D(k)$ represents the time interval k. N_D is the number of the time interval. $Q(l)$ represents queue l. $\sum_{l=0}^{6} PA_{S(i)}^{D(k)}(Q(l))$ represents the number of passengers who enter lifeboats through all queues and complete embarkation during the time interval k in scenario i. $NPA_{S(i)}^{D(k)}$ represents the set of the number of embarked passengers during all of the time intervals in scenario i.

2.3.3. Last Transfer Time. When waiting in the queue, passengers will transfer to the queue with fewer people by their preference or transfer to queues of the lifeboat with more empty seats under staff guidance. The timing of transfer out of the queue reflects the tendency of passengers to complete embarkation through the queue. Whether passengers act under their willingness or staff guidance is determined, and the earlier the leaving time of the last transferred passengers of the queue, the sooner the balance would reach between the number of people in the queue and the count of seats remaining in the lifeboat. The time of the last transferred passenger leaving the queue can be expressed as follows:

$$TQ_{S(i)}^{Q(l)} = \max\left\{tq_{S(i)}^{Q(l)}(1), tq_{S(i)}^{Q(l)}(2), tq_{S(i)}^{Q(l)}(3), \ldots, tq_{S(i)}^{Q(l)}(m), \ldots, tq_{S(i)}^{Q(l)}\left(N_{Trans}^{Q(l)}\right)\right\}, \tag{3}$$

where $N_{Trans}^{Q(l)}$ represents the number of passengers transferred out of queue l. $tq_{S(i)}^{Q(l)}(m)$ represents the transfer time of the m th passenger in queue l under scenario i. $TQ_{S(i)}^{Q(l)}$ is the leaving time of the last transferred passengers in the queue l under scenario i, which indicates that the number of passenger in the queue is less than or equal to the count of seats remaining in the lifeboat.

2.3.4. Number of Embarked Passengers through the Queue. The lifeboat has two entrances, and the difference in the number of embarked passengers between two queues can reflect the utilization efficiencies of the two queues. The number of embarked passengers through one of the queues of the lifeboat can be expressed as follows:

$$LPA_{S(i)}^{L(n)}(u) = \sum_{v=1}^{N^{L(n)}} \left(q^{L(n)}(u) \bullet L_p^{L(n)}(v) \right), \tag{4}$$

where $L(n)$ represents the lifeboat n. $N^{L(n)}$ represents the number of passengers entering lifeboat n. $L_p^{L(n)}(v)$ represents the v th passenger entering the lifeboat n, and its value is equal to 1. $q^{L(n)}(u)$ is the queue u of the lifeboat n. If the passengers entering the lifeboat n through queue u, $q^{L(n)}(u)$ equals 1. Otherwise, $q^{L(n)}(u)$ equals 0. $LPA_{S(i)}^{L(n)}(u)$ represents the number of people entering lifeboat n through queue u in scenario i.

3. Construction of Simulation Model

The embarkation process of passengers is a typical discrete event. AnyLogic [41] is a professional software of virtual prototyping environment for designing complex systems, and it is also widely used to simulate the behavior of pedestrian movement and queuing [42–44]. The software provides API interfaces, and users can customize functions according to the simulation needs. The social force model [45, 46] in the software is based on the Newtonian dynamics, and the different motivations and influences between pedestrians could be reflected by each force. Relevant studies showed that the behavior characteristics of pedestrians in evacuation could be simulated by the social force model, and the model has also been widely used in pedestrian evacuation simulation [47, 48]. Therefore, AnyLogic is used in this study to establish the embarkation scenario and simulate the embarkation process.

3.1. Construction of Simulation Scenarios. The simulation scenario is shown in Figure 2. In order to facilitate the simulation and observation of the embarkation process, the appearances of lifeboats are simplified. Hulls and seating areas of the lifeboat are retained, and passengers can enter the lifeboat through two entrances. Considering the obstruction effect of obstacles on the movement of passengers in the simulation process, the wall module of the software was used to build the hull and seat area. The elements constructed by wall modules can form obstacles in the scenario. Passengers need to go around these elements, and then the movement behavior of passengers in the narrow space of the lifeboat could be simulated. The number of passengers to be embarked is set based on the capacities of lifeboats, and there are 756 passengers in each case of the simulation. This study mainly studies the lifeboat embarkation process of the passengers. The initial condition is that the passengers are already located in the embarkation station and waiting for the captain's order to embark. The simulation is ended when all passengers have taken seats inside lifeboats.

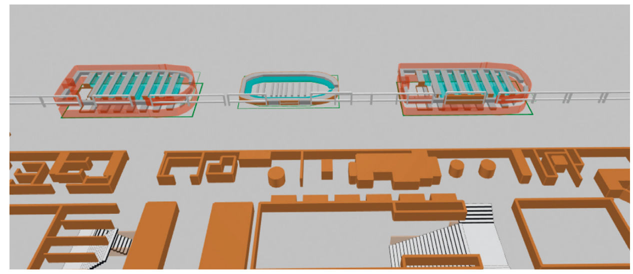


Figure 2: The simulation scenario.

The type, proportion, and speed of passengers in the evacuation simulation are stipulated in the IMO *Guidelines for Evacuation Analysis for New and Existing Passenger Ships* [49], as listed in Table 2. The parameters of passengers in the simulation are set according to Table 2.

3.2. Construction of Simulation Processes. Figure 3 shows the logic chart that is defined in the embarkation model. In the AnyLogic software, the logic chart is used to control the actions of pedestrians, and it consists of functional modules and connecting lines. The PedSource module is used to generate passengers. The group form of passengers can be defined in this module. The Lifeboat_Selection module can separate all of the passengers into several crowds, and functions can be called in this module to control crowds to choose the nearest lifeboat. The Output module includes Lifeboat_1_Output, Lifeboat_2_Output, and Lifeboat_3_Output modules, which could allocate passengers to the nearest queue of the current lifeboat. The pedServiceQueue module can simulate the queuing behavior of passengers, and this module adopts the rule of first in first out. When passengers enter the double-deck lifeboat, the Level_selection module determines whether passengers select upper or lower seats. Passengers who choose the lower seats will enter the lower level through the pedChangeLevel module. LookingForSeat module can realize the function of seat selection behavior of passengers. The Pedsink module is used to remove passengers from the current simulation scenario. In addition, the Cancel function in the pedServiceQueue module can redistribute transferred passengers to the Output module for the transfer process between queues in one lifeboat. If passengers wish to transfer between all queues, the passengers have been redistributed to the Output module and will be reallocated to the Lifeboat_Selection module once again. Then, the transfer behavior of passengers between all queues can be realized.

In the AnyLogic software, Java can be used to custom items that include functions, parameters, and so on. These

Table 2: The percentage and walking speed of passengers.

Passengers	Percentage of passengers	Walking speed (m/s)	
		Minimum	Maximum
Females younger than 30 years	7	0.93	1.55
Females 30–50 years old	7	0.71	1.19
Females older than 50 years	16	0.56	0.94
Females older than 50, mobility impaired (1)	10	0.43	0.71
Females older than 50, mobility impaired (2)	10	0.37	0.61
Males younger than 30 years	7	1.11	1.85
Males 30–50 years old	7	0.97	1.62
Males older than 50 years	16	0.84	1.4
Males older than 50, mobility impaired (1)	10	0.64	1.06
Males older than 50, mobility impaired (2)	10	0.55	0.91

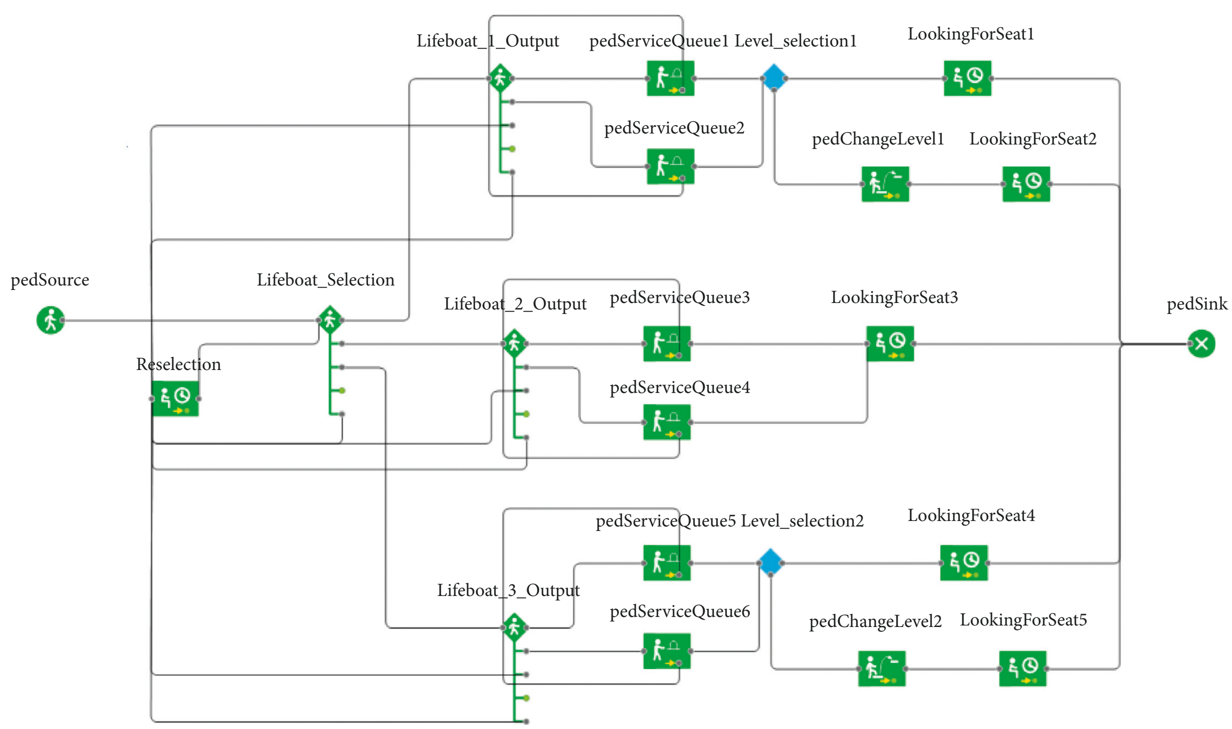


Figure 3: The logic chart for the embarkation model.

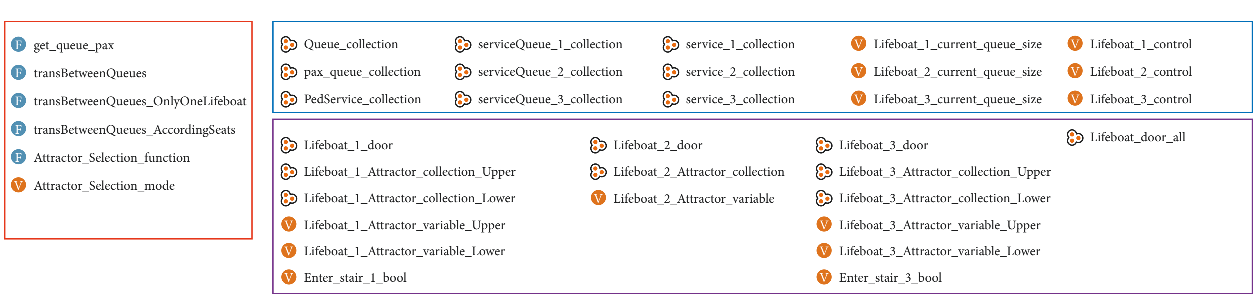


Figure 4: Functions and parameters of the model.

items can be called during the model run. Figure 4 shows the main functions and parameters that are defined in the model. The items defined in the red box are used to realize the function of the passenger transfer between queues and seat selection. The parameters of queues are defined in the blue box, and these parameters are used to obtain passengers' information in the queue. Parameters in the purple box are related to the position of seats and entrances of lifeboats. Details of the functions and parameters can be seen in Table S1 of Supplementary Materials.

Figure 5 shows the pseudocode of the transBetweenQueues. The algorithm can obtain the lengths of all

```
Procedure transBetweenQueues
Begin
    clear pax_queue_collection
    for i←0 to size of Queue_collection do
    begin
        get member variables of all queues from Queue_collection and add these member
        variables into pax_queue_collection
    end
    for i←0 to size of pax_queue_collection do
    begin
        get current values of member variables of all queues and store these values into
        pax_queue_collection
    end
    /* transfor_probability represents transition probability between queues; sum represents
    current numbers of passengers in all queues; queue_aver represents current average numbers
    of passengers in all queues */
    transfor_probability ← random number between 0 to 1
    sum ← 0.0
    queue_aver ← 0.0
    for i←0 to size of pax_queue_collection do
    begin
        sum += current size of each queue
    end
    queue_aver=sum/current size of Lifeboat_door_all
    /* list_ser_ped represents the passenger who transfers out */
    for i←0 to size of pax_queue_collection do
    begin
        if the size of the current queue is great than queue_aver then
            temp ← the size of the current queue - queue_aver
            for j←0 to temp do
            begin
                clear list_ser_ped
                if transfor_probability>=0.5 then
                    randomly select a passenger from (the size of the current queue -
                    queue_aver) passengers at end of the current queue and store the passenger
                    into ped_out
                    get the current queue of the passenger from the ped_out
                    remove the current queue from the list that the passenger would transfer
                    remove queues whose size is greater than queue_aver from the list that the
                    passenger would transfer
                    remove the passenger from the current queue
            end
    end
end
```

Figure 5: The pseudocode of the trans between queues.

queues and allows passengers to reselect other queues after they leave the longer queues.

Figure 6 shows parameters, the function, and the statechart of the passenger model. Items in the left part of the figure are the function and passengers' parameters, including ID, location, selected queue, and the wayfinding mode of the passenger. The chart in the right part is related to the current state of the passenger. If the passenger takes a seat, the status of the passenger is changed from standing to seating state by calling this statechart.

The embarkation simulation is run by combining the customized logic chart, functions, and parameters. The specific simulation process is shown in Figure 7, which includes the following steps:

Step1: select simulation scenarios, which include the ways of grouping, the transfer rule, and the preference of seat selection.

Step2: all passengers would be loaded into the simulation scenario, and passengers act alone or in groups based on the selected type of group.

Step3: passengers choose the nearest lifeboat and form queues at the entrances of the lifeboat. In group mode, passengers in the same group would select the same queue.

Step4: based on the selected scenario, passengers move forward in the queue and prepare to transfer between queues belong one lifeboat or all queues.

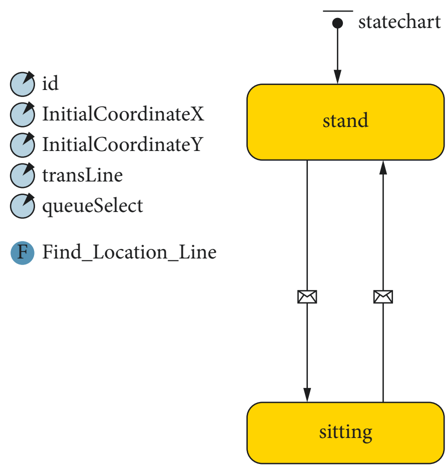


Figure 6: Parameters, the function, and the statechart of the passenger model.

Step5: judge lengths of all queues, the passengers at the end of the longer queue are randomly selected, and then these passengers would be transferred to the shorter queue. If in the rule of considering the seat availability of lifeboats, the number of remaining seats inside the lifeboat will first compare with the number of passengers in queues of the lifeboat. If the number of passengers in current queues is greater than or equal to the remaining seats, crowds of queues belonging to other lifeboats will not be transferred to the current queues even though the current queues are shorter. On the contrary, the extra passengers in the current queues will be transferred to queues of other lifeboats with more remaining seats. If there are still passengers remaining outside the lifeboat when the lifeboat is full, these passengers would be transferred to the queues of other lifeboats in the meanwhile.

Step6: passengers who are transferred would move to a new queue, while other passengers would stay in the original queue. As passengers continue to move forward in the queue, step 6 is repeated if they are selected to be transferred again.

Step7: when passengers enter the entrance of the lifeboat, they will choose the upper or lower seats with a probability of 0.5 if the lifeboat is a double deck. If the lifeboat is a single deck, passengers will directly select seats.

Step8: based on the preference of seat selection, passengers would choose seats randomly or from outboard row to inboard row and complete the embarkation process finally.

4. The Discussion of Simulation Results

Figure 8(a) shows the process of passengers moving towards lifeboats and forming queues. Figure 8(b) displays the process of passengers entering the lifeboat through the queue, and passengers in the red circle area were transferring between queues. The seat selection behavior of passengers is shown in Figure 8(c).

The embarkation characteristics of passengers were analyzed through simulations of 16 types of embarkation scenarios, and each scenario was run 100 times. The values in Figures 9–12, and S1 are mean values of the 100 simulation experiment results, and the error bars represent the standard deviation of the results.

4.1. Analysis of the Total Embarkation Time. Figure 9 shows the total times for passengers to complete embarkation in 16 types of scenarios. For scenarios of individual passengers, the embarkation time in the TAL-IRSS scenario is the longest, while the TSLSA-ISSOI scenario is the shortest. The total embarkation time of the TAL-IRSS and TSLSA-ISSOI scenarios is 1100 and 739 seconds, respectively, and the time of the TSLSA-ISSOI scenario is 32.8% less than that of the TAL-IRSS scenario. In scenarios of group passengers, scenarios that have the longest and shortest total embarkation time are the TAL-GRSS and TSLSA-GSSOI. The total embarkation time of the TAL-GRSS and TSLSA-GSSOI scenarios is 1199 and 891 seconds, respectively, and the time of the TSLSA-GSSOI scenario is 25.7% less than that of the TAL-GRSS scenario. It shows that values of total embarkation time were affected by transfer and activity rules.

From the perspective of transfer rules, the total embarkation time of the four subscenarios contained in TSL and TSLSA rules was smaller than the corresponding subscenarios under TAL and TALSA rules, respectively. It can be found that the embarkation efficiency of passengers transfer between queues of the same lifeboat was higher than they randomly transfer between all queues. The reason may be that the transfer between queues of the same ship can keep the balance of the number of people in these queues preferentially, which could improve the embarkation efficiency of the current lifeboat.

The total embarkation time of subscenarios under TSLSA and TALSA rules was shorter than that of TSL and TAL rules, respectively. This result indicated that transfer between queues based on the seat availability of lifeboats could reduce the behavior of passengers blindly moving to a lifeboat that has shorter queues but fewer remaining seats. In the same transfer rules, the total embarkation time of IRSS and ISSOI rules was smaller than that of GRSS and GSSOI rules, respectively, showing that the embarkation efficiency of the individual passenger is higher than that of the group passenger. In addition, the total embarkation time of IRSS and GRSS rules was longer than that of ISSOI and GSSOI rules, respectively, demonstrating that passengers could complete embarkation earlier if they select seats from outboard row to inboard row. When passengers selected seats randomly, passengers who entered at an earlier time may seat near the entrance hindered the movement of passengers who entered at a subsequent time, resulting in the increase of embarkation time.

4.2. Distribution Analysis of Numbers of Embarked Passengers within Time Intervals. Figure 10 shows the number distribution of embarked passengers within time intervals. Before 200 seconds, the embarkation completion rate of IRSS,

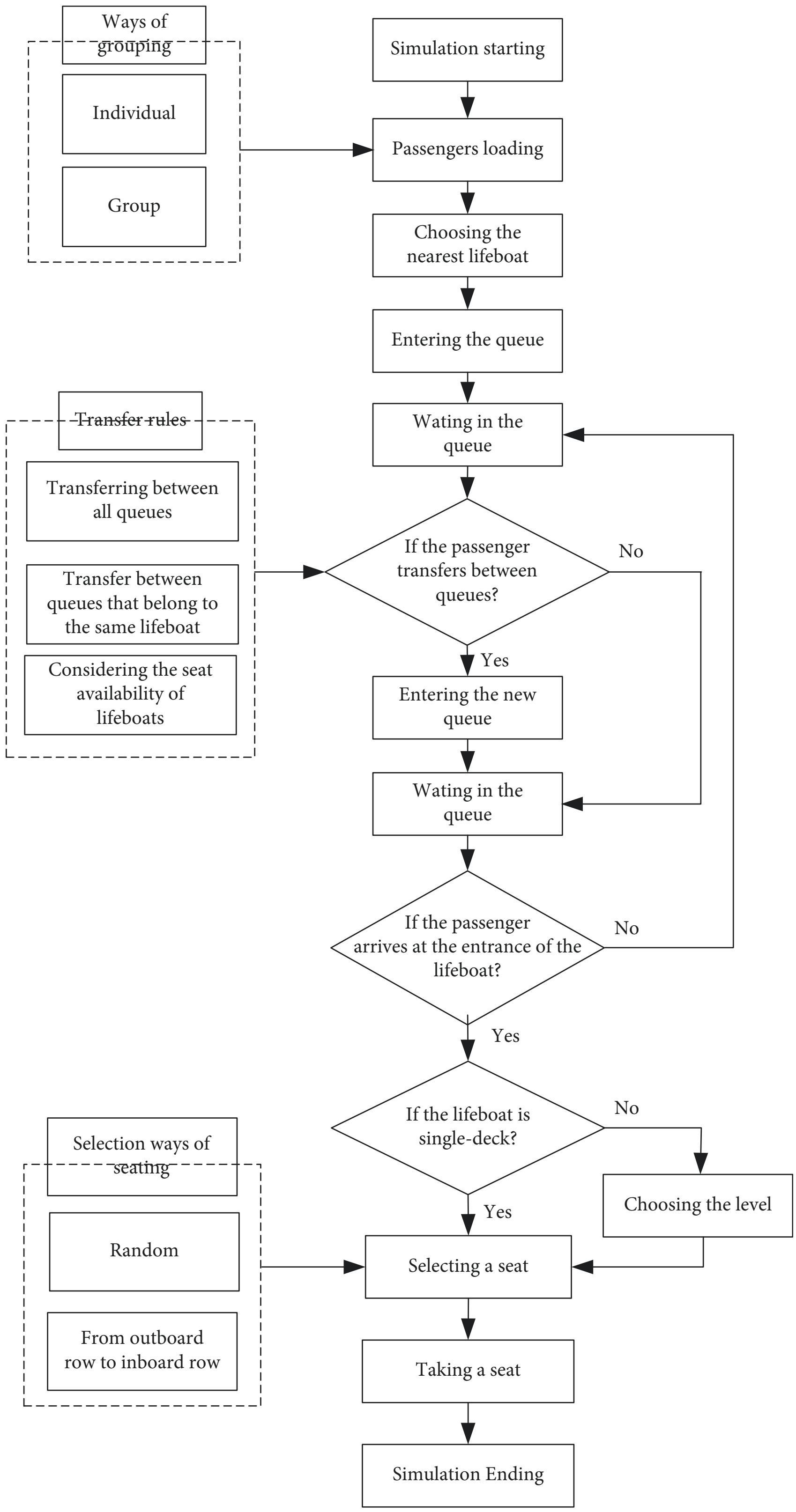
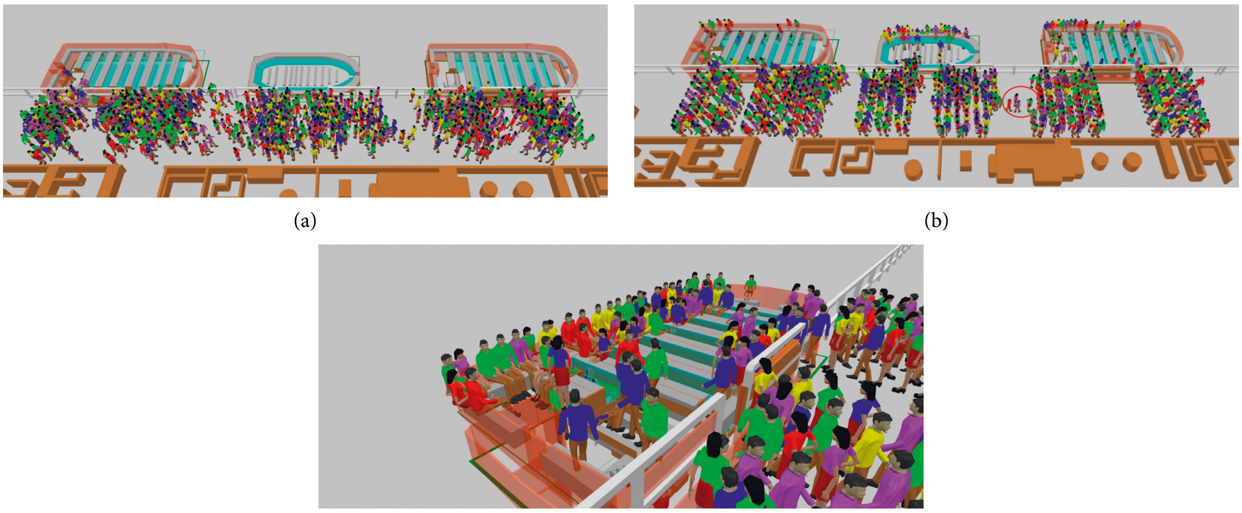


Figure 7: The process of passenger embarkation simulation.

GRSS, ISSOI, and GSSIO rules is a little distinction under the four transfer rules. Within 200–600 seconds, the results of IRSS, GRSS, ISSOI, and GSSIO under different transfer rules gradually began to show obvious differences, which indicated that the embarkation efficiency was impacted by the transfer behavior of passengers. Moreover, the number of embarked passengers in the four subscenarios of TSLSA and TALSA rules was greater than that in the scenarios of



(a) (b)

(c)

Figure 8: Snapshots of the embarkation simulation. (a) The passengers form queues. (b) The passengers transfer between queues. (c) The passengers take their seats in the lifeboat.

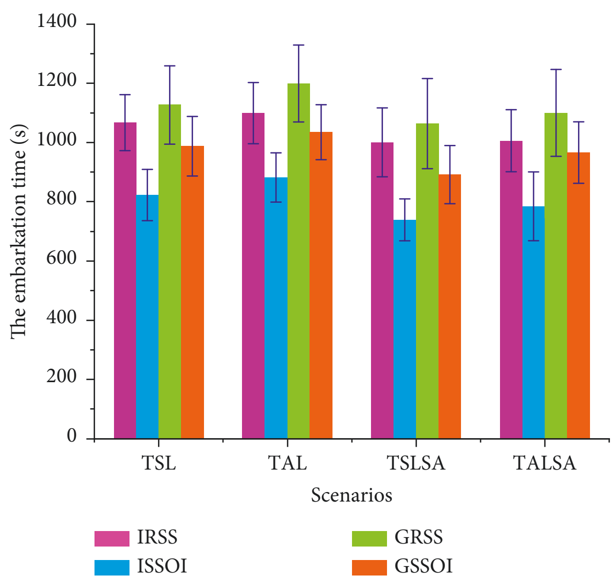


Figure 9: Total embarkation times of passengers.

TSL and TAL rules during this period. This phenomenon demonstrated that the queue transfer considering the seat availability of lifeboats could improve the embarkation efficiency of passengers, which was consistent with the result in Figure 9.

In all scenarios, the peak time of passengers' completed embarkation was around 100 seconds when they acted alone, and slightly more than 200 seconds when they acted in groups. The peak time in the two action modes was both in the early stage of the embarkation process. Figure 13 shows snapshots of the embarkation process. In Figure 13(a), the number of passengers in the lifeboat was small at the initial stage of the embarkation process, and passengers could quickly enter the lifeboat and take seats. In Figure 13(b), passengers at the entrance cause obstacles to subsequent entering passengers as the embarkation process progresses, which reduced the number of embarked passengers per unit time. Therefore, the embarkation efficiency would decrease as the number of passengers increased inside the lifeboat at the initial stage of the embarkation process. While in the middle stage of the embarkation, the number of embarked passengers decreased also related to the lifeboat 2. Lifeboat 2 can be filled earlier for its capacity is small. When lifeboat 2 is full, the number of passengers who could complete the embarkation would be decreased in unit time. Thus, the embarkation efficiency at this stage was also related to the state of lifeboats. As shown in Figure 10, the number of embarked people within 300-500 seconds suddenly decreased.

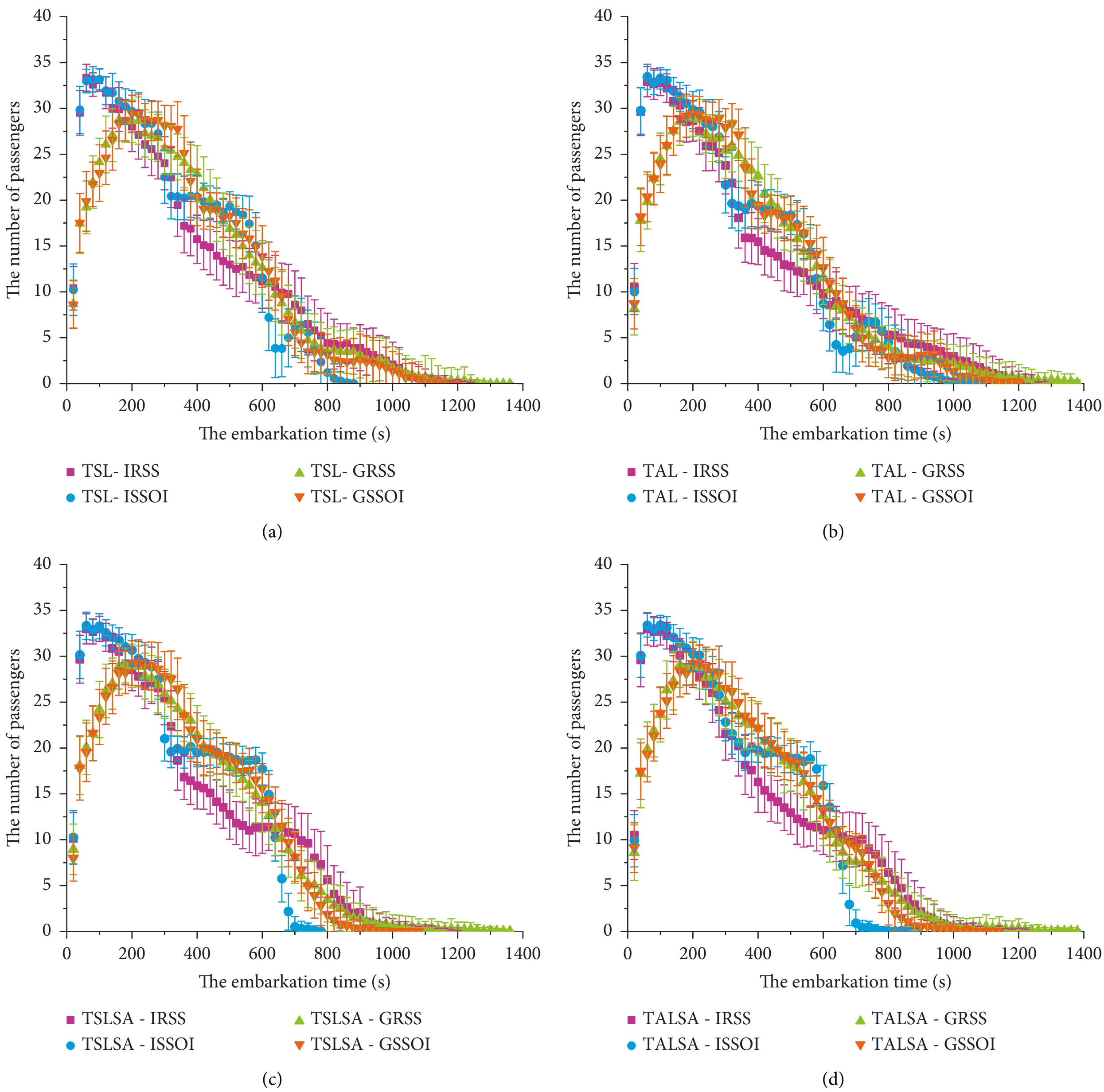


Figure 10: The number distribution of embarked passengers within time intervals. (a) The TSL rule. (b) The TAL rule. (c) The TSLSA rule. (d) The TALSA rule.

4.3. Analysis of the Last Transfer Time. Figure 11 shows the time of the last transferred passenger leaving the queue. In all scenarios, the last transfer times of queues 3 and 4 were significantly smaller than that of the other queues. Queues 3 and 4 belonged to lifeboat 2, and the capacity of this lifeboat was the smallest that could be filled full quickly. Therefore, the excess passengers in these two queues could be transferred to other queues earlier. Under TSL and TAL rules, the last transfer time of queues 3 and 4 was equal, indicating that excess passengers of two queues were transferred out simultaneously as long as lifeboat 2 was full.

In TSLSA and TALSA rules, passengers in these two queues would be gradually transferred to other queues in advance due to the consideration of the seat availability of lifeboats. Therefore, there may be a distinction in the process of passengers transferring out from these two queues, resulting in the difference in the last transfer time between these two queues. The last transfer time of queues 2 and 5 was significantly longer than that of the other queues. These two queues belonged to lifeboats 1 and 3, respectively. As these two queues were close to lifeboat 2, passengers in queues 3 and 4 would choose queues 2 and 5 as the prime target queues for transfer. Therefore, the number of passengers in the queues 2 and 5 was more than in queues 1 and 6, resulting in that the last transfer times of these two queues were also later than other queues.

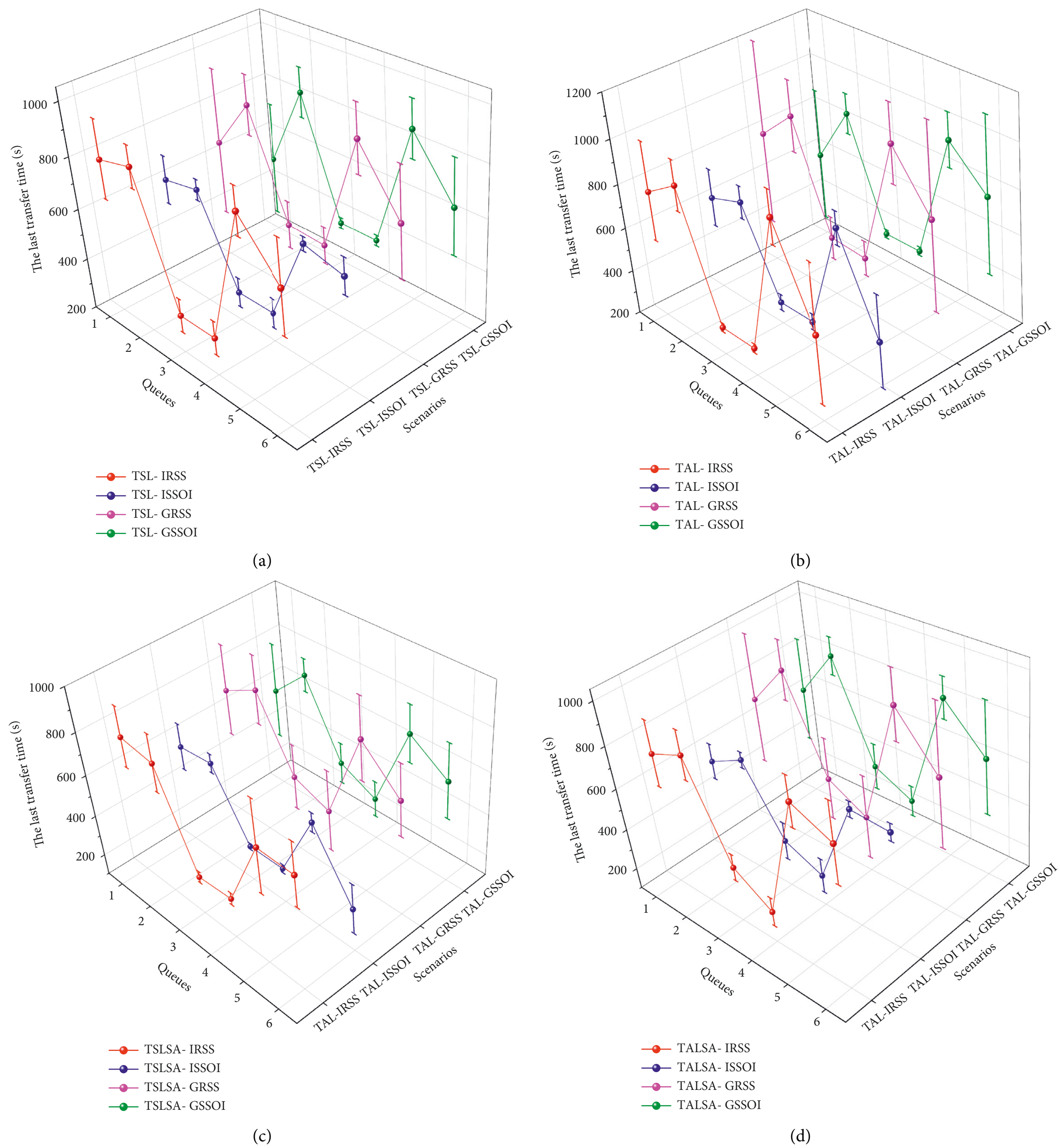


Figure 11: The time of the last transferred passenger leaving the queue. (a) The TSL rule. (b) The TAL rule. (c) The TSLSA rule. (d) The TALSA rule.

4.4. Analysis of the Distinction in the Number of Embarked Passengers between Two Queues of Each Lifeboat. Figure 12 shows the distinction in the number of embarked passengers between two queues of each lifeboat. Each cylinder represents the ratio of the number of embarked passengers from two queues of one lifeboat. The lower part of the cylinders of lifeboats 1, 2, and 3 represents the proportion of the number of embarked passengers entering through queues 1, 3, and 5, respectively. Conversely, the upper part of the cylinder represents queues 2, 4, and 6, respectively.

In most scenarios, the number of embarked passengers entering through queues 2 and 5 was more than that of queues 1 and 6. Especially for the TSL-GRSS, TSL-GSSSOI, TAL-GRSS, TAL-GSSSOI, TALSA-GRSS, and TALSA-GSSSOI scenarios, the difference in the proportion of embarked passengers between the two queues belonged to the same lifeboat was more pronounced. This distinction was

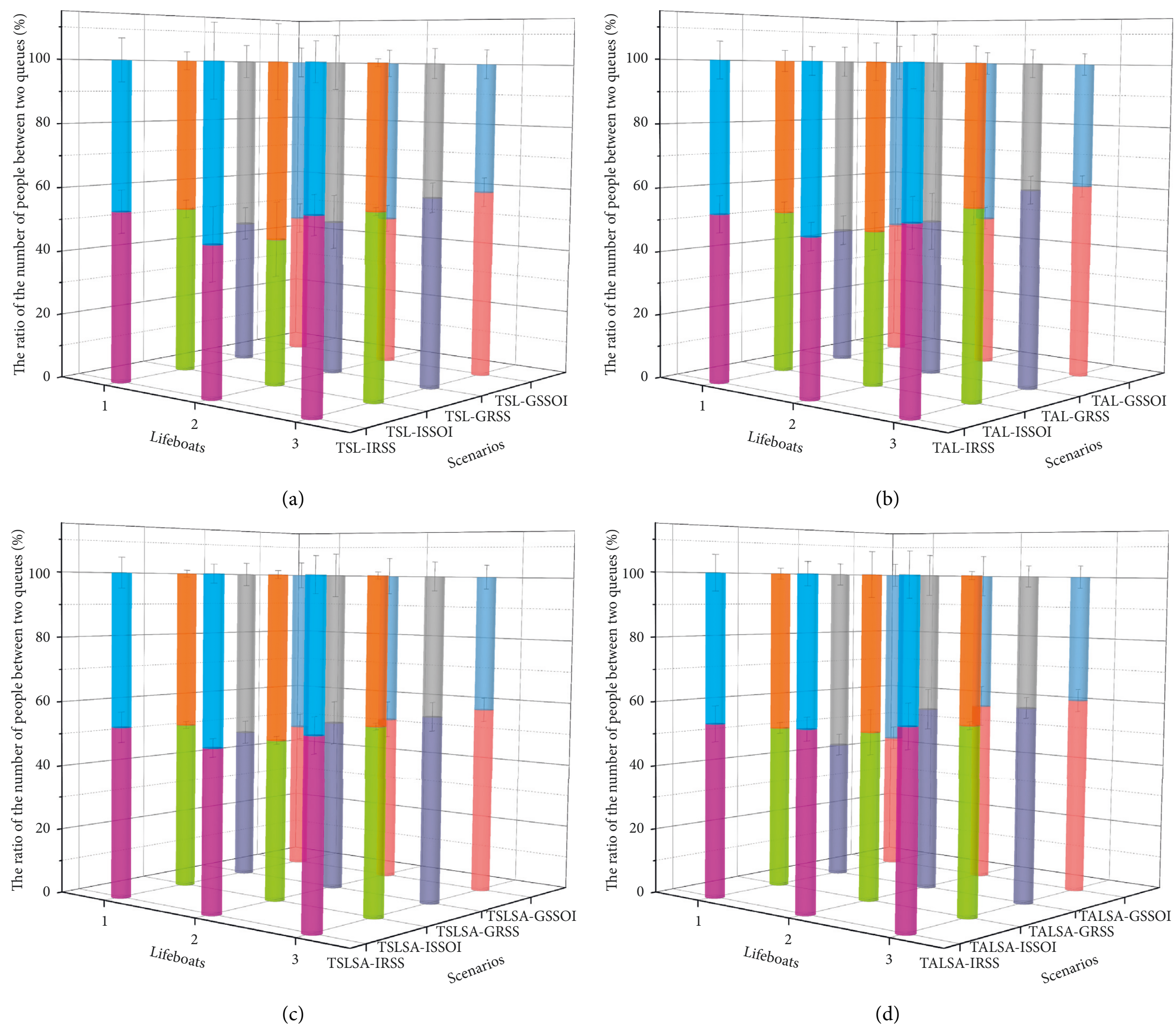


Figure 12: The difference in the number of embarked passengers in two queues of each lifeboat. (a) The TSL rule. (b) The TAL rule. (c) The TSLSA rule. (d) The TALSA rule.

Figure 13: Snapshots of the embarkation process. (a) The running time is 60 s. (b) The running time is 120 s.

mainly reflected in that there were more embarked passengers in queues 2 and 5 than in queues 1 and 6, which was consistent with the result in Figure 11. Compared with TAL and TALSA rules, the ratio of two parts of the cylinder under TSL and TSLSA rules was closer to 50%. As known from Figure 9, the total embarkation time of the four subscenarios under TSL and TSLSA rules was shorter than that under TAL and TALSA rules, respectively. It showed that the balance of the number of passengers in queues belong one lifeboat could be better maintained if passengers transfer between queues of the same lifeboat, which could also improve the embarkation efficiency.

5. Conclusions and Future Works

This study examined the lifeboat embarkation process of cruise passengers. By dividing the embarkation process into queuing and seat selection stages, transfer rules of queue and activity rules of the passenger were proposed. Based on the rules, 16 types of embarkation scenarios were constructed, and embarkation processes of these scenarios were simulated.

The simulation results showed that the embarkation efficiency of passengers was high in the early stage. As the progress of the embarkation, the passengers who had entered the lifeboat caused obstacles to the subsequent passengers, and the embarkation efficiency was gradually decreased. It was advantageous for passenger embarkation to select seats from outboard row to inboard row than select seats by random. The embarkation efficiency of passengers transfer between queues of the same lifeboat was higher than they randomly transfer between all queues. In addition, the embarkation efficiency would be improved again if the queue transfer was based on the seat availability of lifeboats. An obvious result of the study is that the total embarkation time of the TSLSA-ISSOI scenario is 32.8% less time than the TAL-IRSS scenario, and the total embarkation time of the TSLSA-GSSOI scenario is also 25.7% less than the TAL-GRSS scenario.

We also tested the embarkation time of passengers under the mixed rule, as shown in Figure S1. The mixed rule combines all transfer and seat selection rules, and it mainly reflects that some of the passengers acted autonomously under the guidance of the staff. The results show that the embarkation time under the mixed rule is longer than the single rule under the guidance of the staff (TSLSA-ISSOI and TSLSA-GSSOI) and shorter than the single rule under the autonomous action of passengers (TAL-IRSS and TAL-GRSS). Even if some of the passengers still kept their own willingness and did not act on staff guidance, the embarkation efficiency is still higher than that without the guidance of the staff. It is proved that under the guidance of the staff, appropriate queue transfer and seat selection rules can effectively improve the embarkation efficiency of passengers.

The limitation of this study is that the simulation result has not been compared with experimental data of the object ship. In order to perfect the rules proposed in this study and apply them to improve the embarkation efficiency of cruise ships, it is necessary to carry out passenger embarkation experiments and use experimental data to improve the queue transfer and seat selection rules in future work.

Data Availability

The data used to support the findings of this study are available upon request to the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Supplementary Materials

Detailed information on Table S1 and Figure S1 is presented in the supplementary materials as follows: (1) Table S1: details of the functions and parameters in the model. (2) Figure S1: the embarkation time of passengers under mixed rule. (*Supplementary Materials*)

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Research Article

Design of College Students' Sports Assessment System Based on Data Mining

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In order to improve the quality of modern physical education (PE) and let PE teachers get rid of the busy data management, this article puts forward the design of an assessment system about sports performance based on data mining and introduces the scheme of the system in detail. Based on NET three-tier architecture, the demand of users is analyzed, combined with web technology, SQL database platform, and the theory of data mining. The technical architecture of the system and the design of the database are discussed, and the realization of the functional module of sports achievement management is implemented. The system is tested so that the accuracy is verified in use. At the same time, the system runs well after testing and application. Through this system, PE teachers can realize the management and statistics of sports performance, reduce the intensity of teachers, and enable PE teachers to devote themselves to improving the quality of PE teaching.

1. Introduction

In the process of China's social and economic progress, China's education system is undergoing continuous reform, and the requirements for comprehensive physical fitness and high-quality talents are getting higher than before. In modern society, students not only need good grades but also have a demand for physical fitness so that they can make advances in future work [1]. This also meant that physical education is the foundation of other disciplines, students' sports test also began to count their total scores, and the view that sports is not so important has been gradually changed [2]. As for the calculation of sports achievement, it is mainly through the test of students' PE class, such as high jump, long jump, and 300-meter dash, which are converted into specific scores according to the relevant regulations of the school. Because of the diverse content of PE courses, much achievement data are produced in the implementation of testing. Teachers have to implement the data conversion and input them into the school educational administration system. The results are made by hand movement under heavy workload so that the work efficiency cant be improved, which restricts the sustainable development of physical education [3, 4]. To solve these problems, we need a data statistics and analysis system that can make PE teachers get rid of heavy tasks, effectively solve these problems, and optimize inner work so as to give full play to the guiding role of teachers in PE teaching.

With the rapid development of computer technology, data mining is constantly improving, and more and more companies and enterprises are beginning to use data mining technology to improve their own management system [5], which constantly promotes the prosperity of their companies. For data mining technology, it is widely used in major companies. However, the application in colleges is relatively less because colleges pay more attention to theoretical knowledge, and data mining technology is less used in the management system of colleges [6–8]. But in fact, this is a loss to the management system of colleges. Due to the lack of application, the related management of students is rather heavy, which results in lower working efficiency. The data mining technology has the advantages of good performance, simple operation, and easy employment. Due to these advantages, the rapid development of this technology is constantly promoted [9]. In view of the problems in modern PE teaching, this article utilizes information mining innovation to understand the programmed handling and analysis of data on sports achievement, which is convenient for students to inquire about their scores and teachers' statistics so as to continuously improve the efficiency and teaching quality of the college.

2. Introduction to Related Technical

2.1. ASP.NET Technology. ASP.NET is developed by integrating ASP and NET technologies [10, 11]. ASP.NET is applicable to a wide range of each field, such as the dynamic process of website design. Compared with other technologies, ASP.NET has its own unique advantages. It mainly includes the following points: (1) ASP.NET is a newly developed technology, which is popular among people, and it integrates the advantages of both ASP and NET technologies; (2) ASP.NET has a wide range of database resources, and it can translate many languages, which is convenient for people to use; (3) ASP.NET has been developed on the basis of various technologies, which has many functional advantages and is easier to operate than others [12, 13].

It can be seen from Figure 1 that ASP.NET is mainly composed of three parts, which are mainly divided into the user layer, business logic layer, and data access layer.

(1) The user layer, also known as the presentation layer, is a layer directly facing customers, and all interaction between users is the responsibility of this layer. Therefore, in the application of this layer, It is necessary to build a concise appearance to facilitate users' operation [14].

(2) Business logic layer located in the middle layer is mainly used to calculate and process business-related logic. This layer plays a connecting role and is the core layer of the three layers [15].

(3) Data access layer, which mainly represents various operations on the database, provides various data services for the previous layer and feeds back the processing results.

These three layers are related and interlocking. Reasonable adjustment of these layers can not only improve the operating efficiency of the company but also improve the economic benefits of the enterprise. Moreover, these components have their own unique advantages, and at the same time, the operation and use are relatively simple and practical.

2.2. Database of SQL Server. SQL is a structured language for querying, and SQL Server is a database management system. The database management system is used for storing all kinds of data used in the system, and at the same time, various operations of data, including query, modification, and deletion, are realized by transferring SQL statements. This kind of database management system is mostly used to develop a distributed system, which is convenient to operate. Moreover, it is powerful, can realize various functions of accessing and operating data, and provides a concise user interface to learn [16, 17].

The database system of the sports assessment system is SQL Server 2005, which was chosen because of its unique advantages, as follows: (1) the application of distributed view greatly improves the speed of accessing the database and the work efficiency, while the distributed view can quickly locate the data [18]; (2) it supports multiple development languages, including XML and other languages; (3) it has better performance and higher reliability; (4) it encapsulates a variety of technologies that are commonly used to realize data integration; (5) SQL Server 2005 provides users with a virtual network of the interface system.

2.3. Data Mining. In brief, data mining is to extract or "explore" knowledge from data in quantity [19, 20]. Many people regard data mining as another term data that is commonly used.

It is synonymous with knowledge discovery in database (KDD) in mining database, while others just regard data mining as a link of KDD, which is a process of extracting useful patterns from data automatically and efficiently using specific algorithms of data mining. KDD is a cyclic process including data mining and data preparation.

At present, there is no exact definition of "data mining." A relatively accepted definition is put forward by W.J. Frawley, G. Piatetsky-Shapiro, and others: that is, data mining is an extraordinary process to obtain patterns that are correct, novel, potentially applicable, and finally understandable from data [21].

Information mining is a multistage process and can, for the most part, be isolated into three principal stages: information readiness, information mining, and result articulation and translation. KDD is an iterative process of the three stages. The specific process can be described in Figure 2 [22].

2.3.1. Stage of Data Preparation. Data preparation represents the biggest extent in the entire course of information mining, which as a rule, comes to around 60%. This stage can be additionally separated into three substeps: information choice, information preprocessing, and information change [23–25]. Information determination basically alludes to separating pertinent information from the current dataset or information distribution center to frame information focused on. Information preprocessing processes the extricated information to meet the necessities of information mining. Its main job is to check spelling mistakes, remove duplicates, and make up incomplete records. Data transformation is mainly to normalize data. For example, continuous data is converted into discrete data to facilitate symbol induction; likewise, the discrete data can be converted into continuous data in order to unify the dimension (or dimensionless) so that all index data can be uniformly processed in various algorithms.

2.3.2. Stage of Data Mining. At this stage, the task of mining, such as data classification, clustering, discovery of association rule, or sequential pattern, should be determined first

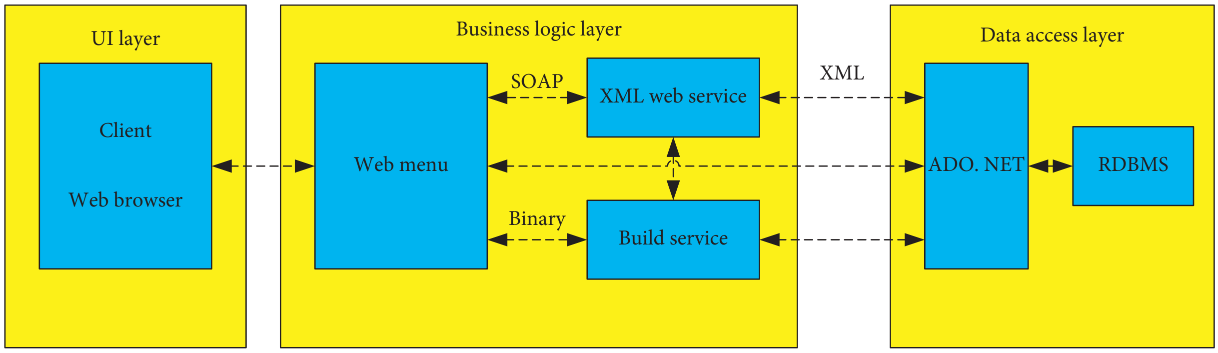

Figure 1: Three-layer structure based on ASP.NET.

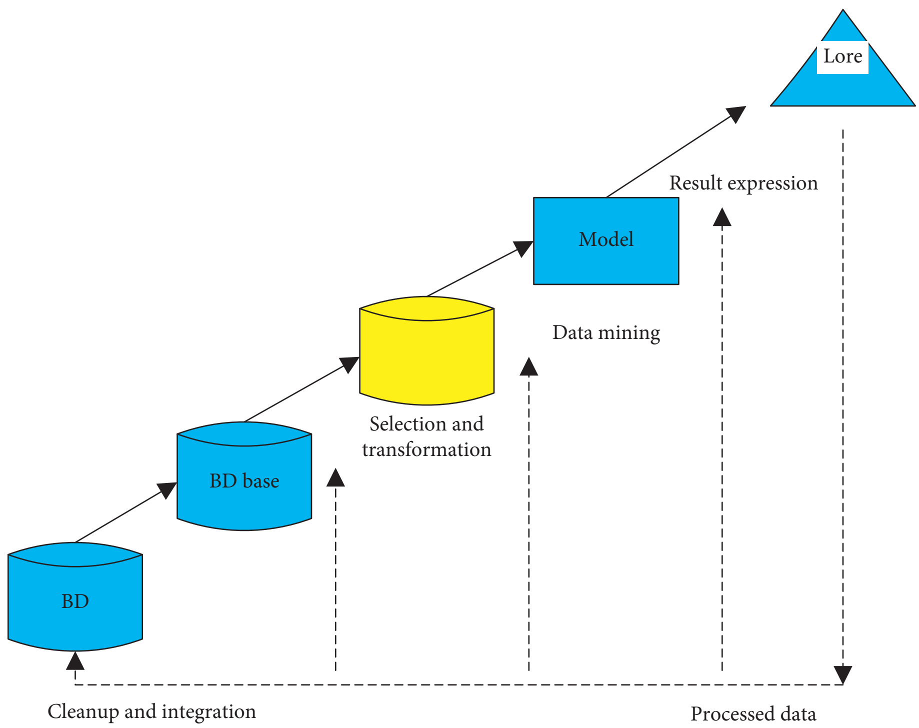

Figure 2: Process knowledge discovery in database.

[26]. After determining the mining task, it is necessary to decide which mining algorithm to use. The choice of algorithm is the most important factor in the data mining stage and the key factor related to the effectiveness of acquired knowledge, which directly affects the quality of mining patterns. The algorithm should be selected according to the characteristics of data and the actual requirements of users [27]. After finishing the arrangements above, you can run the calculation of information mining. This stage is the most concerned by data mining investigators and specialists in related fields, which can be called data mining in the genuine sense.

2.3.3. Expression and Explanation of Results. Knowledge discovery mode in the stage of data mining can analyze and evaluate the extracted information according to the purpose of the end user's decision [28], while can also distinguish the valuable information and eliminate patterns that are redundant or irrelevant. For the mode that cannot meet the user's requirements, it is necessary to return to the previous stage, such as reselecting data and adopting methods of new data transition. Set new parameter values, or even change a mining algorithm.

3. Overall Design of System

3.1. Demand Analysis. In terms of physical education, teachers have to face the realistic problem of a huge workload at the stage of examination. With the increasing attention paid by the state to students' corporeity, how to establish a perfect performance assessment system and carry out more targeted teaching through the statistics and management of students' PE achievements over the years is an important issue for physical education. The users of the system are administrators, teachers, and students, while different roles correspond to different operation permissions and users need to log in with their personal account and password. The system provides users with different permissions according to personal account information and then completes the operation of corresponding permissions. There are many categories of sports test items, and the test methods, scores, and scoring methods are different. Therefore, it is necessary to set different scoring forms according to different items when calculating scores, and the total score of each item is 100 points. The addition, modification, and deletion of these test item categories need to be achieved by the system.

3.2. System Design. The design of the target system is based on data mining through detailed exchanges and discussions with related PE teachers in colleges. Aiming at various problems in the management of sports achievements, the design and development scheme of the sports assessment system is put forward to solve the problems faced in the current management of sports through the application of the target system, which frees the PE teacher from the busy work in the past and realizes the automation and informatization of the management of sports achievements. Figure 3 shows the overall diagram of sports achievement management.

From the figure above, it is known that there are three types of users that the target system faces, namely, PE teachers, students, and system administrators. The three types of users can perform different system operations. The system administrator has the greatest authority and can perform any function in the system. PE teachers can perform other functions except for system management. In contrast, students have the least corresponding permissions and can only perform functional operations about performance management.

The development of the system is based on the. NET three-layer structure divides the whole application into three layers, namely, presentation layer, business logic layers, and data access layers [29]. The presentation layer is a user-oriented application layer, which is responsible for completing the interaction with users. This layer usually uses the interface to complete the interaction by designing some controls on the interface [30]. It is only responsible for receiving access requests sent by users and feeding back the final results to users, and it does not need to be careful about the specific method to realize users' requests. The business layer is located between the presentation layer and the data access layer, which is the core link of the logic processing of the whole system, and is responsible for the logical calculation and processing of the user's request while receiving the data from the data access layer at the same time. The data layer works for gaining data and executing programs and feeding the processing results back to users. Figure 4 shows the architecture of the system.

4. Function Module Design of the System

The overall functional structure diagram of the system is shown in Figure 5.

It can be seen from the figure that the system consists of five functional modules, namely, test type management, test project management, score management, score analysis, and system management.

4.1. Management Test Type. Test type refers to items related to sports test, which is stipulated by the syllabus. Test type management includes operations related to test types, including adding test types, modifying test types, deleting test types, and setting weights. Figure 6 shows the functional block diagram of test type management.

(1) Increase test type: it means adding a new test type. During the process of adding, the system will verify the content added by the user, including whether it is blank or legal.

(2) Test type modification means to modify the existing sports test types and save the user's modified results to the corresponding type database.

(3) Test type deletion: delete the original test type in the database. In the process of deletion, the deletion object selected by the user will be judged whether there are test items under the test type. If there are any, the user will be prompted that the test type cannot be deleted, and the type can only be deleted if it is determined that there are no test items.

(4) Score weight setting: it refers to setting the relevant proportion of the score weight under each test type.

4.2. Test Project Management. Test projects refer to specific projects involved in sports tests, such as high jump, long jump, and basketball. Test projects management refers to the management of business related to test projects. Figure 7 shows the functional structure diagram of test project management.

(1) Increase test projects: it means adding new test projects. During the process of adding, the system will verify the contents added by users, including whether they are blank and legal.

(2) Test projects modification means relevant modification operations are carried out on the existing sports test projects, and the user's modified results are saved in the corresponding type database.

(3) Delete test projects: delete the original test projects in the database.

(4) Point weight setting: it refers to setting the relevant proportion of the score weight under each test project.

4.3. Performance Management. Performance management refers to the related management of students' sports performance, including the entry of performance, the modification of performance, the deletion of performance, the inquiry of performance, the export of performance, and the conversion of scoring system. Figure 8 shows the functional structure diagram of performance management.

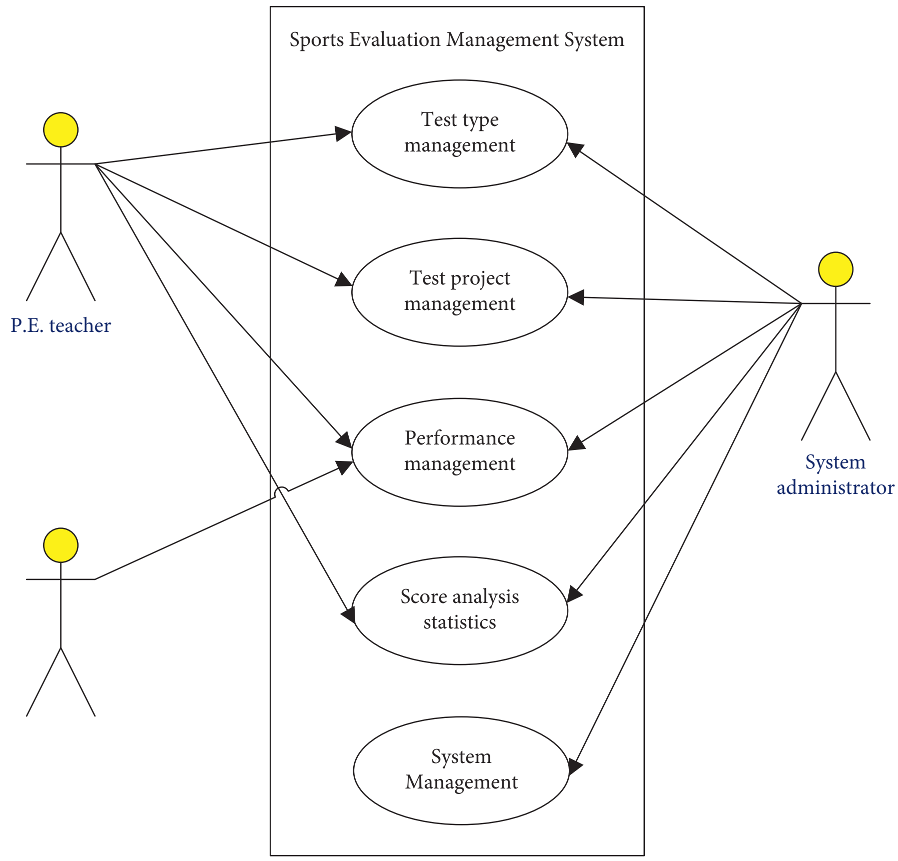

Figure 3: General use case diagram system.

(1) Input: it means that students' sports scores are entered into the score database of the system. In the process of score entry, the data entered by the user will be verified, including whether it is blank or legal. Only after confirming that both of them are satisfied will a new piece of information be inserted into the database to complete the entry.

(2) Modification: modify the original scores in the system and save the modified results into the score database of the system.

(3) Deletion: delete the original scores in the system and save the deleted results.

(4) Inquiry: by querying students' performance by entering specific query conditions, these conditions can include the student's student number, and the student's name or score range.

(5) Export: export the data related to students' sports achievements to Excel tables, which is convenient for statistics and decision-making.

(6) Conversion: it is converted into the corresponding points system according to students' scores.

4.4. Statistical Analysis of Achievements. Statistical analysis is to count the students' sports performance and analyze the statistical results using the algorithm of data mining. This is the core function of the target system. The functional structure diagram of the score analysis is given as shown in Figure 9.

(1) Score statistics: It means that students' sports performance is quantized to obtain the total score or average score. It also supports showing these statistical results in the form of charts or words, which is convenient for users to consult.

(2) Score analysis: It is the core part of the score analysis module, which refers to the analysis of students' scores using the algorithm of data mining.

4.5. System Management. System management refers to the management and maintenance of all the basic information of the target system. The main work includes the functions of user addition, user modification, user deletion, permission allocation, database backup, and database restoration. System management is the essential basic function module of every software. The following is the functional structure diagram of system management, as shown in Figure 10.

(1) User addition: it means adding users who enter the target system. The types of users targeted by the system include students, PE teachers, and system administrators.

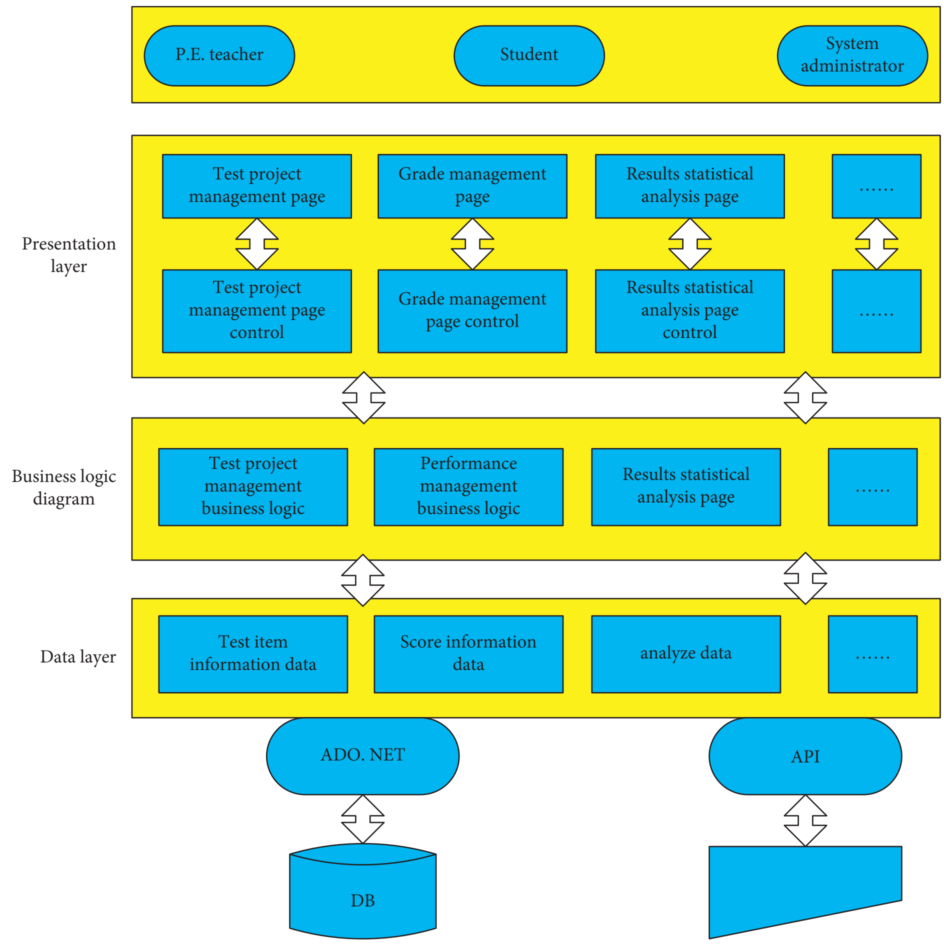

Figure 4: Overall technical architecture of the system.

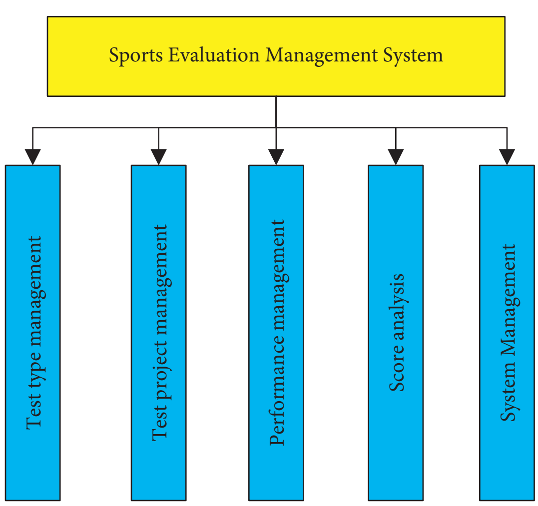

Figure 5: Overall functional structure of the system.

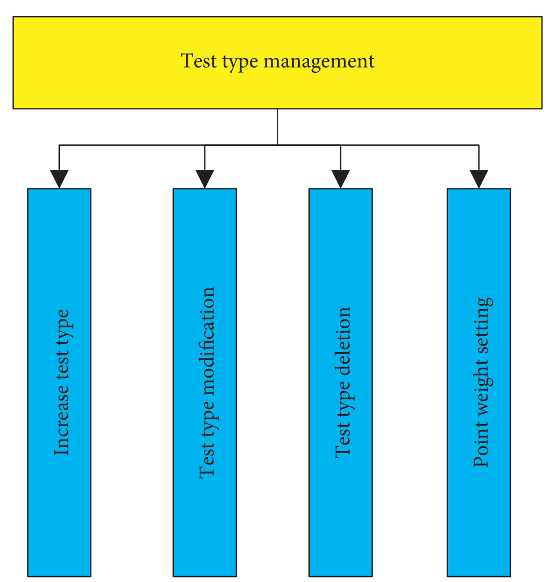

Figure 6: Functional structure diagram of test type management.

(2) User modification: it refers to the modification of basic information of users, including modification of users' password and modification of personal information of users.

(3) User deletion: it refers to the logout operation for information-related users who have entered the system.

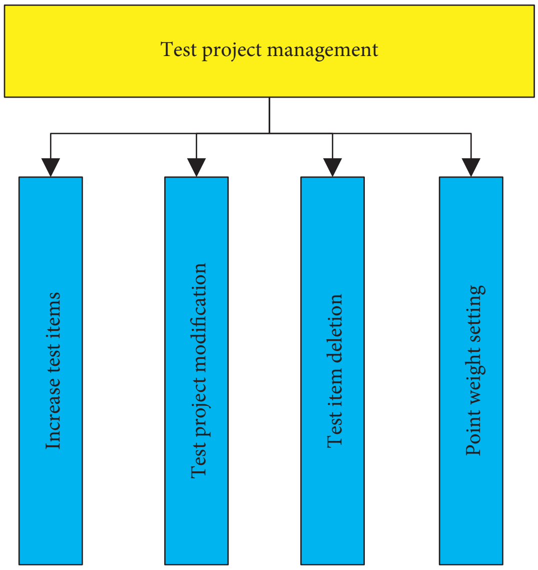

Figure 7: Functional structure diagram of test project management.

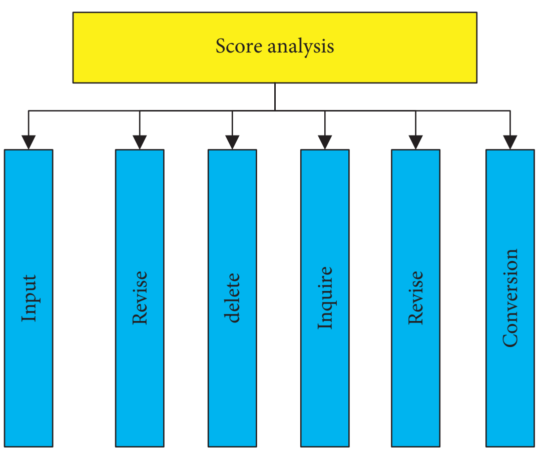

Figure 8: Functional structure diagram of performance management.

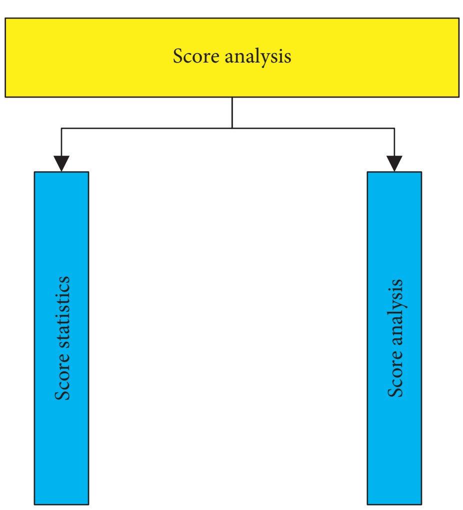

Figure 9: Functional structure diagram of score analysis.

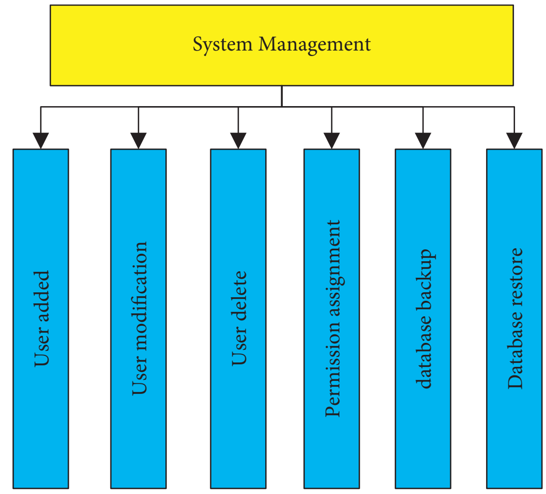

Figure 10: Function structure diagram of system management.

(4) Permission assignment: it allocates relevant permissions for users entering the system.

(5) Database backup: it is used to back up the database of the system.

(6) Database: it restores the database of the system.

5. Design of System Database

5.1. Design of Database System. According to the detailed analysis of the target system, the data table is designed here combined with the conceptual design and logical design of the system's database.

Table 1 shows the information table of users, which is mainly applied to store information related to the system, including ID, name, login Miyun, and type of users.

Table 2 shows the information table of students, which is mainly applied to store various information related to students, including name, ID, and login password of students.

Table 3 shows the table of test type, which is used to store various information related to test types, including test type name, type description, and weight.

Table 4 shows the table of test projects, which is mainly used to store various information related to test projects, including ID, name, type, description, and score weight of test projects.

Table 5 shows the table of test score, which is mainly applied to store the basic information related to students' test scores, including the test score number, test projects, student ID, and score.

Table 6 shows the table of students' achievement, which is used to store the basic information related to students' achievements, including grade ID, student ID, and total score.

Table 7 shows the conversion table of the points system, which is used to store the basic information needed for the conversion of the points system, including score ID, maximum score, minimum scores, and conversion name.

5.2. Application of ID3 Learning Algorithm. Data entropy, called normal data in the principle of data, is a normal worth

Table 1: Information table of user.

Field name	Data type (length)	Primary key	Null	Describe
Yong Hu ID	Int	Yes	No	User ID
Yong Hu Ming	varchar(20)	No	No	Username
Mi Ma	varchar(20)	No	Yes	Login password
Lei Xing	Bit	No	No	User type

Table 2: Information table of students.

Field name	Data type (length)	Primary key	Null	Describe
Xue Sheng ID	Int	Yes	No	ID
Xue Sheng XM	varchar(20)	No	No	Student name
Xue Hao	varchar(11)	No	No	Student ID
Mi Ma	varchar(20)	No	No	Login password

Table 3: Test type table.

Field name	Data type (length)	Primary key	Null	Describe
Ce Shi Lei Xing ID	Int	Yes	No	Test type ID
Lei Xing Ming Cheng	varchar(20)	No	No	Test type name
Lei Xing Miao Shu	Text	No	Yes	Test type description
Lei Xing Quan Zhong	Int	No	No	Test type weight

Table 4: Test item table.

Field name	Data type (length)	Primary key	Null	Describe
Ce Shi Xiang Mu ID	Int	Yes	No	Test project ID
Xiang Mu Ming Cheng	varchar(20)	No	No	Test item name
Ce Shi Lei Xing ID	Int	No	No	Belonging to the test type
Xiang Mu Miao Shu	Text	No	Yes	Test item description
Xiang Mu Quan Zhong	Int	No	No	Test item weight

used to quantify the communicated data. The data communicated in the source incorporates a set number of totally unrelated and together complete occasions, all of which appear with a certain probability, which is expressed by the mathematical formula: a group of events $x1$, $X1, \ldots, X_r$, which appear with a given probability $p(X1)$, $p(X_r)$, the mean value $H(X)$ is the information entropy, and it is equal to the mathematical expectation of the (self) information amount $I(X)$ of each event, namely,

$$\begin{aligned} H(X) &= -\sum_{r=1}^{r} p(Xi) I(Xi) \\ &= -\sum_{r=1}^{r} p(X_i) \log p(X_i). \end{aligned} \tag{1}$$

ID3 algorithm achieves the best classification in the algorithm according to the attribute of maximum information entropy and the principle conducive to the classification. The gain of information of an attribute will reduce the information entropy of the system, and the key operation of the ID3 algorithm is to calculate and compare the information of each attribute. It is needed to take a representative training sample as an example to introduce the decision tree node, which determines whether the samples are in the same category. By selecting the best classification attribute of the sample as the node attribute and dividing the samples, according to this node attribute, the maximum standard value is obtained. If samples are lacking in a branch, the sample types of the training cluster need to be compared.

6. Implementation of System

6.1. Types of Sports Test. Management of sports test types includes various functional modules: addition of test types, modification of test types, deletion of test types, and setting of weights. The database tables involved in these module tests mainly include test type tables, and the corresponding database program statements are Insert, Modify, and Delete. Among them, the program of test type deletion is shown in Figure 11.

6.2. Projects of Sports Test. The executives of sports test projects allude to the administration of data connected with sports test and its practical modules chiefly include the following: expansion of sports test projects, setting of weight, alteration, and cancellation of sports test projects. The tables of dataset engaged with the execution basically incorporate the data table of test projects. Some key codes of realization of functions are given as follows. First, the program gets the information entered by the user on the page. Among them, the procedure of added test projects is shown in Figure 12.

Table 5: Test score table.

Field name	Data type (length)	Primary key	Null	Describe
De Fen ID	Int	Yes	No	Score number
Ce Shi Xiang Mu ID	Int	No	No	Test items
Xue Hao	varchar(11)	No	No	Student ID
Fen Zhi	Int	No	No	Points

Table 6: Student achievement sheet.

Field name	Data type (length)	Primary key	Null	Describe
Cheng Ji ID	Int	Yes	No	Grade ID
Xue Hao	varchar(11)	No	No	Student ID
Zong Fen Zhi	Float	No	No	Total score

Table 7: Conversion table of the points system.

Field name	Data type (length)	Primary key	Null	Describe
Fen Zhi ID	Int	Yes	No	Point system ID
Fen Zhi Zui Xiao Zhi	Int	No	No	Minimum score
Fen Zhi Zui Da Zhi	Int	No	No	Maximum score
Ming Cheng	varchar(10)	No	No	name

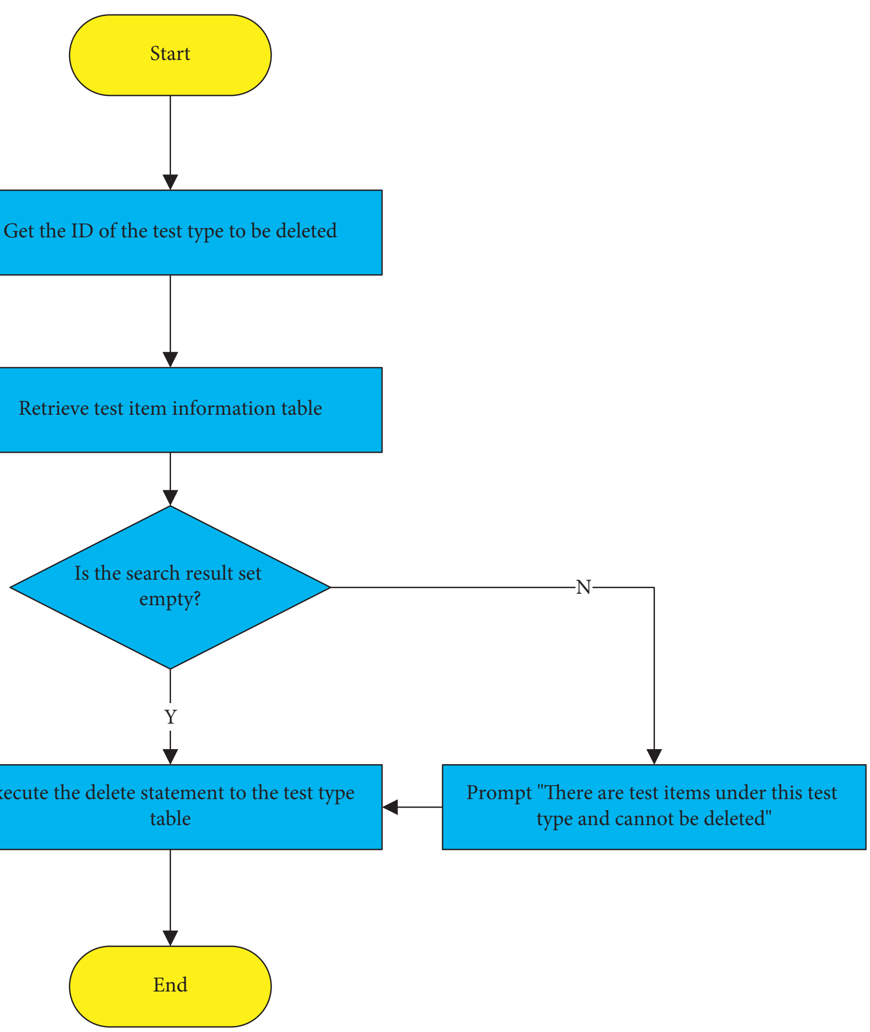

Figure 11: Program of test type deletion.

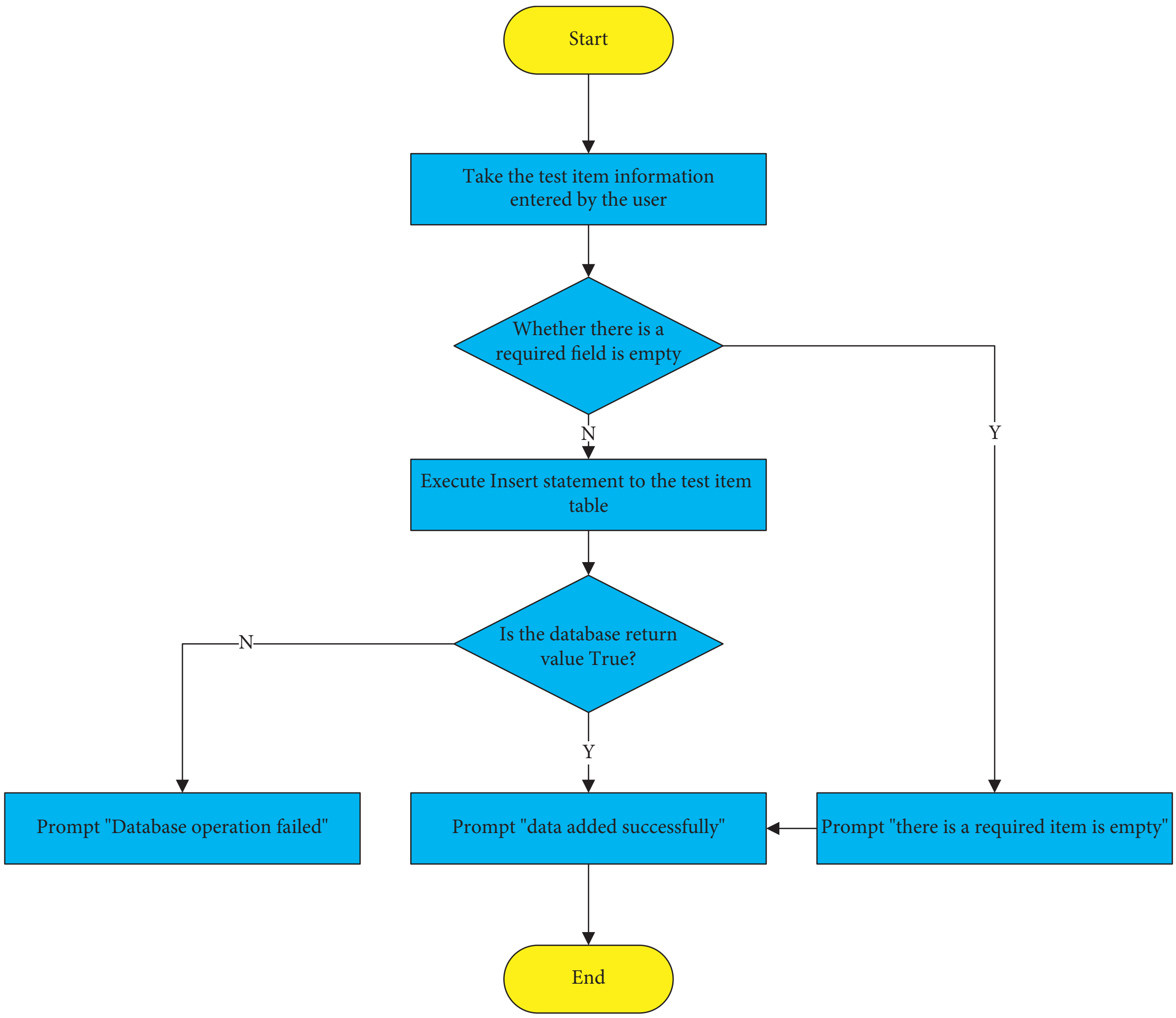

Figure 12: Procedure of added test projects.

6.3. Management of Performance. Management of performance refers to the management of information related to students' sports scores, which includes main functional modules: entry, modification, deletion, inquiry, export of scores, and conversion of point. In these modules, the core part is the entry and calculation of scores. In the process of entry, the tables of the database involved are information tables of scores, and the database tables indicated by calculation are information tables of scores and information tables of performance. Among them, the procedure of score entry is shown in Figure 13.

6.4. Problems and Solutions in the Process of System Testing. The problems and solutions in the process of testing the sports assessment system are as follows:

(1) After the system is installed, statistics of sports scores are made, but their download cannot be completed, and the system will not give a prompt of error. Solution: most of these problems are caused by the fact that office-related software is not installed in the system, which can be implemented after restarting according to the server. If it still cannot work, the permissions of components need to be modified.

(2) An error results in the termination of installation when IIS is registered and the database is coded. Solution: this situation usually occurs because the environment of NET is not installed, or the installed version does not match the version developed by the project; in addition, there is an error in the SQL. The current problems can be solved by improving these two aspects.

6.5. Evaluation of Teachers. After half a year's systematic maintenance, the PE evaluation management system based on data mining technology has been put into use, and it has been well received by PE teachers. Through this system, the workload of PE teachers is greatly reduced, and they are freed from the complicated work of processing data, which effectively improves efficiency, truly replaces manual labor with machines, and promotes the normalization of teaching

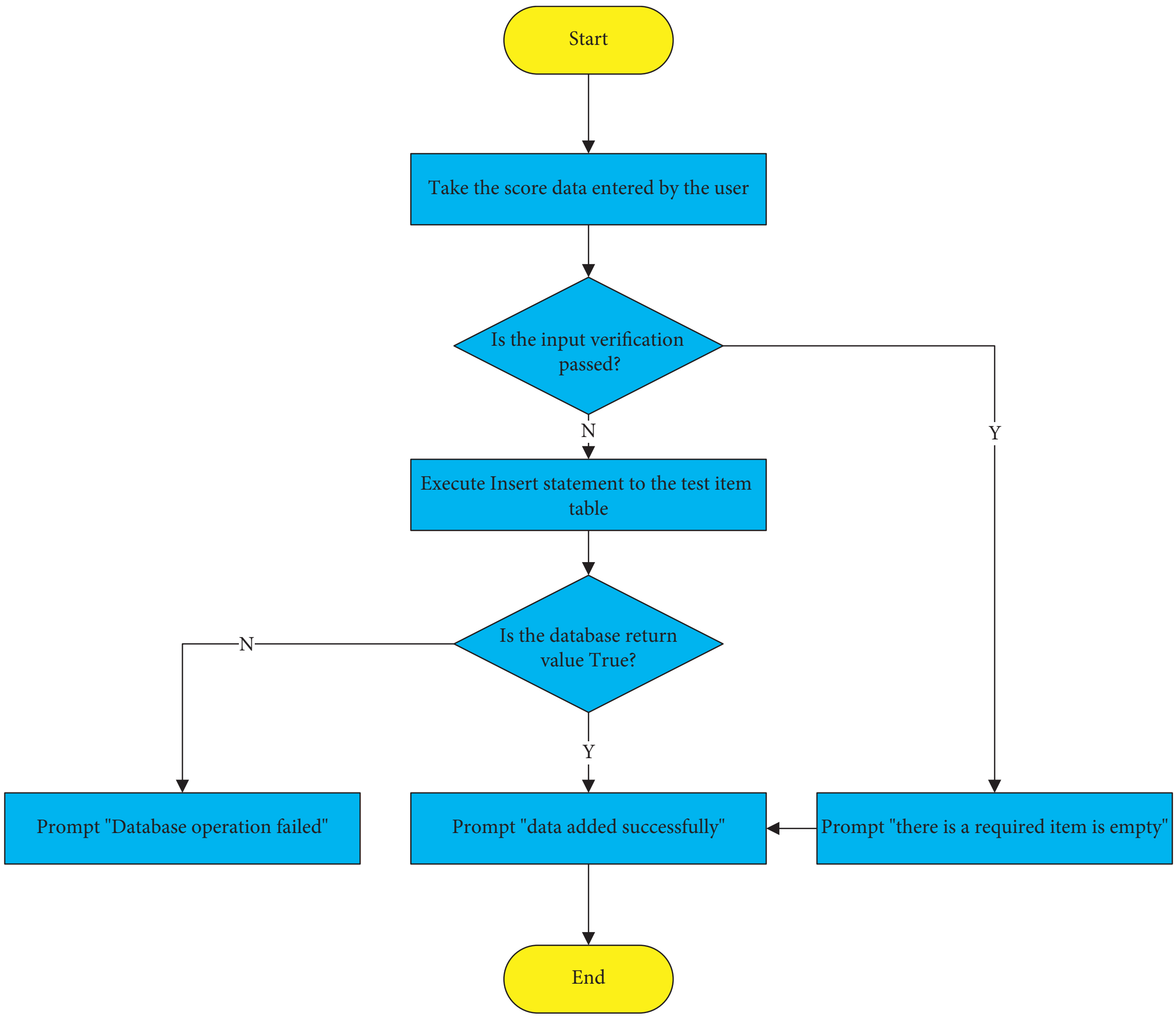

Figure 13: Procedure of score entry.

management through the application of sports management system based on data mining technology.

7. Conclusion

Advances in computer and network technology provide technical support for the information construction of colleges. On the basis of data mining, this article constructs a three-tier sports assessment system, completes the introduction of the system's functional modules and the design of the database, uses the ID3 algorithm to complete the data mining of the system, and finally completes the operation of each functional module. The results of the test show that the system runs stably, and the daily statistics and management of PE teachers' sports scores can be completed more easily through this system, which improves teachers' work efficiency, enables them to devote more energy to the improvement of PE teaching quality, and further enhances the level of automation and information management of physical education scores.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

A New Fast Algorithm for Library Circulation Data Mining Based on FUP

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As the first incremental association mining algorithm, FUP can well solve the problem, but the algorithm also has the deficiencies to produce a large set of candidates and multiple iterating the database, leading to the algorithm's low execution efficiency when dealing with some large transactions with fast updates, such as book circulation data. This study proposes an improved FUP algorithm that takes transaction identifier (TID) in the database to scan the database only once, making the computation significantly less than the FUP algorithm. Through detecting the circulation data of a university library, the experimental results show that compared with the standard FUP algorithm and SFUA algorithm, with the increase of borrowing and record transactions, the improved FUP algorithm has significantly improved the operation efficiency, which can help the library to do a good job in book recommendation scientifically.

1. Introduction

Association mining is a main study direction of data mining. In the research of association mining algorithm, AIS [1], SETM [2], Apriori [3], DHP [4], and other algorithms have appeared successively. The above association mining algorithms that can only mine association rules from static databases [5] belong to static data mining algorithms. However, the actual situation is that it is often necessary to add a batch of new transactions to the original database transaction, or readjust the support degree and confidence threshold. In this case, a method needed to realize the updating problem of association mining. Rule of incremental association algorithm mainly deals with two kinds of problems: dynamic adjustment of threshold and updating of database. Concerning problem of dynamic threshold adjustment, the main representative algorithm is IUA [6] algorithm proposed by Feng Yucai et al, and related algorithms have also been proposed later. Reference [7] adopts the Can-tree sorted by the amount of data to improve the efficiency of frequent itemset mining in space and time. Reference [8] improves alarm prediction accuracy and model training efficiency through the alarm weight and communication prediction plan digging by weighted incremental association rule mining based on Can-tree. Reference [9] proposed a parallel incremental association rule mining algorithm based on information entropy and genetic algorithm to solve the problem of dynamically setting the support degree threshold. There are mainly FUP [10], FUP2 [11], and SFUA [12] algorithms for database updating problems. FUP is the first incremental association mining algorithm, which solves the problem of data update mining well, but it also has some shortcomings, such as generating a large number of candidate itemsets, traversing the database many times and so on. In view of the above shortcomings, scholars have improved this algorithm. Reference [13] uses the combination of strong frequent itemset connection and prepruning to improve the execution efficiency of the algorithm. Reference [14] proposed a method to update association rules efficiently based on attribute change. Reference [15] transforms the dataset into Boolean matrix to reduce the number of scans and storage of the database. Reference [16] combines inverted index technology with tree structure to solve the problems of low efficiency and high computational cost of incremental update mining algorithm.

In this study, an improved FUP algorithm is proposed. The algorithm uses the transaction identifier TID in the database to obtain frequent itemsets. It only needs to scan the database once, and then the candidate itemsets are obtained by connecting L_{K-1} and $L1$, so that the amount of calculation of the algorithm is significantly less than FUP. Through the detection of the circulation data of a university library, the experimental results show that compared with the standard FUP algorithm and SFUA algorithm, with the increase of borrowing record transactions, the improved FUP algorithm has significantly improved its operation efficiency, and can scientifically help the library do a good job in book recommendation.

2. Incremental Association Mining Algorithm

2.1. FUP Algorithm

2.1.1. The Core Idea of FUP Algorithm. Assume the original dataset dB, the new dataset dB and the updated dataset (DB∪db). Frequent itemset LDB in Dataset DB and support degree $\sup_{db}$. The support degree $\sup_{db}$ in new dataset db, minsup is the minimum support degree, and the core idea of FUP algorithm is [17] as follows:

(1) Frequent itemset L_{db} of the dataset db generated by Apriori algorithm, for any frequent itemset t, if $t \in L_{DB}$ and $t \in L_{db}$, then t will be the frequent itemset of the dataset (DB∪db).

(2) For any frequent itemset t, if $t \in L_{DB}$ and $t \notin L_{db}$, count the support degree $\sup_{db}$ of t in db by scanning the new dataset db, then according to the support degree supDB of the original dataset calculate support degree sup (DB∪db) of itemset t by the formula in the updated dataset. If $\sup_{(DB\cup db)}$>minsup, then itemset t is the frequent itemset of database set(DB∪db), otherwise is the infrequent itemset. The formula is: $\sup_{(DB\cup db} = (\sup_{DB}|DB| + \sup_{db} |db|/|DB| + |db|)$

(3) For any frequent itemset t, if $t \in L_{db}$ and $t \notin L_{DB}$, count the support degree $\sup_{DB}$ of t in DB by scanning the new dataset DB, then calculate itemset t according to the support degree $\sup_{db}$ in dataset (DB∪db), if $\sup_{(DB\cup db)} >$ minsup, t is the frequent itemset of database set(DB ∪ db), otherwise is the infrequent itemset.

2.1.2. Analysis of FUP Algorithm. FUP algorithm uses the frequent itemsets and support of the original dataset to generate a much smaller candidate itemset. When updating, it reduces the scanning of the original dataset as much as possible, so as to improve the efficiency of the algorithm. However, the algorithm also has obvious shortcomings [18]:

(1) The consumption of computing support is too large, and the database needs to be scanned many times, which is inefficient.

(2) Candidate itemsets are obtained by Apriori connection. With the increase of the number of items in the database, a large number of candidate itemsets will be generated, and the time complexity of the algorithm will rise sharply.

2.2. FUP2 Algorithm. FUP2 algorithm divides the updated database into ① datasets that remain unchanged after updating; ② additional datasets; and ③ deleted datasets. The algorithm adopts apriori_gen function and the L^1_{K-1} in frequent k-1 itemset of the updated dataset (DB ∪ db) generates a candidate k-itemset C_k, and C_k is a superset of L^1_{K-1}. Then, using the ^K_L in frequent k-itemset of the original dataset DB, the candidate itemset C_k is divided into the infrequent itemset and frequent itemset of the original dataset DB. What's more, the two itemsets are processed to finally obtain the frequent k-itemset of (DB∪db). Compared with FUP algorithm, FUP2 algorithm improves the operation efficiency, but it still uses Apriori algorithm when generating candidate itemsets, which likes FUP algorithm, it will produce too many candidate itemsets.

2.3. SFUA Algorithm. SFUA algorithm is an incremental association mining algorithm proposed by Chen Jinsong and others. The algorithm is mainly based on apriori_gen function in Apriori algorithm generating a collection of frequent itemsets db. Using the property "for itemset X, if $X \in$ LDB, and $X \in$ Ldb, there must be $X \in L$ (DB∪db)." The frequent itemset is divided into three disjoint parts:①a certain itemset is a frequent itemset in both dataset DB and db; ② an itemset is a frequent itemset in DB, while a infrequent itemset in db; ③ a certain itemset is a frequent itemset in db, but it is infrequent in DB

SFUA algorithm scans the dataset as follows: scanning the original transaction dataset DB only once; for the newly added dataset, db scanning $k+1$ times; the aggregate number of scanning is $|DB| + (k+1)|db|$. When the dataset is relative small, the efficiency of SFUA algorithm is truly high. However, when the newly added dataset is large, SFUA algorithm also has the problem of too many frequent itemsets.

3. Improved NFUP Algorithm Based on FUP Algorithm

3.1. Incremental Update Problem Analysis. The improved algorithm is based on the following theorems and properties [19], where $S(X)$ is a set consisting of identifiers, the number of elements in $S(X)$ is the support count of X, C_k is the candidate k-itemset, and Lk is the frequent k-itemset.

Theorem 1. *the necessary and sufficient condition for itemset X to becoming a frequent itemset is: SUP (DB∪db) (X)≥(|DB| + |db|)* minsup*

Theorem 2. *if the itemset X does not belong to the original frequent itemset, the necessary condition for X to become a frequent itemset is: SUPdb(X)≥|db|* minsup.*

Theorem 3. *$\forall C \in C_k$, S(C) can be obtained from two elements S(X) and S(Y) in S_{k-1}, and $S(C) = S(X \cap S(Y)$.*

Property 1. If itemset X is a frequent itemset in (DB∪db), then X is at least frequent in DB or db.

Property 2. If all candidate itemsets C_k can be generated by $L_{k-1} \infty L_{k-1}$ and there is $t \in$ Lk-1, the candidate itemset can also be generated by $L_{k-1} \infty L1$.

From Theorem 1, Theorem 2, and Property 1, combined with the support calculation formula, we can deduce SUPDB(t)+SUPdb(t)≥ (|DB| + |db|)*minsup, that is, to determine whether an itemset is a frequent itemset in the updated dataset, we need to compare whether$\mathrm{SUPDB}(t) + \mathrm{SUPdb}(t) \geq (|\mathrm{DB}| + |\mathrm{db}|)^* \mathrm{minsup}$ is true.

According to the above derivation formula and FUP algorithm, when adding a dataset db to an original dataset DB, the itemset has the following situations:

(1) If an itemset is a frequent itemset in both dataset DB and db, the itemset is also a frequent itemset in dataset(DB ∪ db).

(2) For any frequent itemset t, if there are one of the following two cases: ① $t \in L_{DB}$ and $t \notin L_{db}$② $t \in L_{db}$ and $t \notin L_{DB}$, if judging whether t is a frequent itemset in the dataset(DB∪db), it is necessary to compare the relationship between SUPDB(t)+SUPdb(t) and (|DB|+|db|)* minsup. If the former is bigger than the latter, it is a frequent itemset, otherwise it is a infrequent itemset.

(3) Moreover, t must also be a infrequent itemset in the updated dataset (DB∪db) if $t \notin L_{DB}$ and $t \notin L_{db}$. For cases (1) and (3), it is easy to determine whether they are frequent itemsets, so the improved algorithm focuses on case (2), and the problem is how to quic$_k$ly find frequent itemsets. From Property 2, it is obtained by connecting L_{k-1} and $L1$ when generating the candidate candidate set. The improved algorithm replaces the Apriori algorithm used in the original FUP algorithm to obtain the candidate item set for L K-1 self connection.

FUP algorithm mainly deals with the frequent itemsets of the database. In view of the shortcomings of this algorithm, this study proposes a method NFUP to obtain candidate itemsets by connecting L_{k-1} and $L1$. When generating frequent itemsets, it uses the transaction identifier TID in the database to obtain them. For the generated frequent itemsets, only the transaction identifier TID list and support degree need to be retained. The improved algorithm NFUP only needs to scan the original dataset and the new dataset once.

3.2. Execution Process of NFUP Minimum Support

(1) Scan the original dataset DB and the new dataset db respectively. The candidate item set of DB and db is C^1_{DB}, C^1_{db}, record the transaction identifier TID list corresponding to each item, and get the frequent 1-itemset of DB and db according to the minimum support, and mark them as L^1_{DB} and L^1_{db}.

(2) According to Theorem 3, calculate the support degree of db in DB. The support degreeof L^1_{db} in L^1_{DB} is the support degree of db in DB. According to the formula: $\mathrm{SUPDB}(t) + \mathrm{SUPdb}(t)$, calculate the support degree of L^1_{db} in (DB∪db). If $\mathrm{SUPDB}(t) + \mathrm{SUPdb}(t) \geq (|\mathrm{DB}| + |\mathrm{db}|)^* \mathrm{minsup}$ is true, it is the frequent itemset of (DB∪db), otherwise it is the infrequent itemset. In order to avoid repeating operations, L^{11}_{DB} obtained from the same items in L^1_{DB} and L^1_{db} that deleted from L^1_{DB}, and calculate the support degree of L^{11}_{DB} in db. If the support degree of L^{11}_{DB} in db is empty, it means that an item in DB has never appeared in db. Then continue to calculate the support degree of L^{11}_{DB} in (DB ∪ db). If it is bigger than $(|\mathrm{DB}| + |\mathrm{db}|)^* \mathrm{minsup}$, this item can be retained as a frequent itemset.

(3) Merge the frequent itemset of L^1_{db} in (DB ∪ db) and the frequent itemset of L^{11}_{DB} in (DB ∪ db) to obtain the frequent 1-itemset of $L^1_{(\mathrm{DB} \cup \mathrm{db})}$ in (DB∪db).

(4) $k > 1$, Calculate and itemsets of L^k_{DB} and L^k_{db}, obtain $L^1_{(\mathrm{DB} \cup \mathrm{db})}$ and respectively prune according to step (3), then obtain L^{12}_{DB} and L^{12}_{db}. Adopt improved Apriori_gen algorithm in L^{12}_{DB} and L^{12}_{db} to generate candidate itemset of L^{12}_{DB} and L^{12}_{db}. The idea of improvement followed by Property 2 shows that the candidate itemset C_k can also be generated by $L_{k-1} \infty L1$. The choice of L_{k-1} is related to k. when $k = 2$, it is actually $L1$ connecting $L1$, and $L1$ is the frequent one item set after pruning.

Continue to perform steps (1), (2) and (3) in the above process to obtain the frequent itemset k of (DB ∪ db) until the candidate itemset $k + 1$ of (DB ∪ db) is empty till the execution process ends.

3.3. NFUP Main Function Execution Function

(1) Build identifier Get_TID( ) function of 1 item collection

Get_ TID (database) function:
(1) $C_1 = \{$database collection$)\}$
(2) for all item $C \in C_1$ do $S(C) = c//S$ contains a set of identifiers, c is each item of $C1$
(3) end for
(4) for all $t \in$ Database do//an item in S
(5) $C_t = \mathrm{subset}(t, C_1)$
(6) for all $C \in C_t$ do $S(C) = S(C) \cup$ t.TID( )//build the identifier of 1-itemset to form 1 collection

(2) The process of generating candidate itemsets Apriori_gen( ) function

Apriori_CI( ) function:
(1) for all $l_{k-1} \in L_{k-1}$ do//l_{k-1} is one item of L_{k-1}
(2) for all $l_{k-1} \in L1$ do

(3) $l_{k-1} = l_{k-1} \infty l_1$
(4) $S(l_k) = S(l_{k-1}) \cap \cup S(l_1)$//generate k-itemsets
(5) Ct = subset(t, C_1)//gets a list of identifiers for the k-itemset

3.4. Case Analysis of NFUP. In order to better understand the process of finding frequent itemsets using NFUP algorithm, examples are listed for analysis. The original dataset DB is known, and the minimum support is 4. The specific information is shown in Table 1. Add a new dataset db with a minimum support of 2. The specific transaction data are shown in Table 2. The minimum support value of the updated dataset (DB ∪ db) is 6.

The process of mining frequent sets using the improved NFUP algorithm is shown in Figure 1.

Scan the original dataset DB and the new dataset db respectively to obtain the candidate item set. In Figure 1. ①, C_{DB}^1, C_{db}^1 are the candidate item sets of the original dataset and the new dataset respectively. Then the frequent itemsets L_{DB}^1, L_{db}^1 of DB and db are obtained according to the minimum support. Here, corresponding identifier and each item obtained from the improved algorithm Get_TID( ) function.

In Figure 1. ②, according to Theorem 3, the support degree of L_{db}^1 in DB is counted, and the support degree of db in (DB ∪ db) is calculated. The support degree of $\{I_1\}$ in DB is 3, and that in db is 4. According to the formula SUPDB(I_1) + SUPdb(I_1), 3 + 4>6 is calculated, so { I_1} is the frequent 1-itemset in (DB∪db). Similarly, $\{I_2\}$ is also the frequent item set in (DB∪db). $\{I_3\}$ and $\{I_5\}$ are infrequent itemsets via validating. To avoid repeating operations, delete the same items in L_{db}^1 and L_{DB}^1 from L_{DB}^1, and the remaining itemset is $\{I_4\}$. Count the support degree of { I_4} in the dataset (DB∪db). First calculate the support degree of $\{I_4\}$ in db. If $\{I_4\}$ does not appear in, the support count is 0, that is, the support degree of $\{I_4\}$ in L_{db}^1 is 0, the support degree of $\{I_4\}$ in L_{DB}^1 is 8, and 0 + 8 is bigger than the minimum support degree of 6, so it is determined that $\{I_4\}$ is the frequent itemset of (DB∪db). Merge and obtain the frequent 1-itemset $\{I_1, I_2, I_4\}$ of (DB∪db).

In Figure 1. (2), prune L_{DB}^1 and L_{db}^1 respectively according to the frequent 1-itemset of (DB∪db). Adopt the improved Apriori_gen algorithm to generate candidate itemsets, and then obtains two frequent itemsets C_{DB}^2 and C_{db}^2 . The same as the above calculation process, counte the L_{db}^2 in frequent 2- itemset of (DB∪db) and L_{DB}^2 in the frequent 2-itemset of (DB ∪ db). The obtained frequent 2-itemsets are: $\{\{I_1, I_4\},\{I_2,I_4\}\}$. Because L_{db}^2 in the frequent 2-itemset of (DB ∪ db) is empty, the frequent 3-itemset in (DB∪db) is empty, and all frequent itemsets in (DB ∪ db) are $\{I_1,I_2,I_4, \{I_1, I_4\},\{I_2,I_4\}\}$. It is consistent with the mining results of FUP algorithm.

4. Application of NFUP in Library Circulation Data

In order to test the feasibility and effectiveness of the improved incremental data association rule mining algorithm, library circulation data is used for detection. Test environment: 4G memory, CPU 2.50 ghz, window7 operating system, test software: WEKA.

Table 1: Dataset DB.

TID	Itemset
$T1$	I_1,I_2,I_4,I_5
$T2$	I_1,I_2,I_3,I_4
$T3$	I_1,I_2,I_4,I_5,I_6
$T4$	I_3,I_4
$T5$	I_1,I_3,I_4,I_6
$T6$	I_1,I_2,I_4,I_5
$T7$	I_2,I_3,I_4
$T8$	I_1,I_2,I_3,I_4,I_5,I_6

Table 2: New dataset db.

TID	Itemset
$T1$	I_2,I_3
$T2$	I_1,I_2,I_3,I_5
$T3$	I_1,I_2,I_5
$T4$	I_1,I_3,I_5,I_6
$T5$	I_1,I_2

4.1. Data Preprocessing. The mining data comes from the borrowing information of students from August 2017 to July 2019 exported from the management system of a university library. There are 110,326 records of the exported borrowing information. The core data in the borrowing information is shown in Table 3. Data cleaning, integration, selection and other processing work are carried out for borrowing information, and the processed data is 35,232 records. For the processed data, the book is classified by the retrievable number, and the classification number is A—Z, in which the classification number A—Z corresponds to 22 major categories in the Chinese library. The borrowing records are generalized to obtain the borrowing record transactions. The information in the transaction table is shown in Table 4.

4.2. Analysis of Association Rule Mining Results. Given the minimum support degree is 15%, the confidence is 40%, and 3,000 new data are added, the mining results are shown in Table 5.

From the mining results, 70.732% of the students who borrowed T-books borrowed F-books at the same time. 68.731% of the students who borrowed H-books and I-books simultaneously. The probability of H and I-books being borrowed at the same time is 34.413%, and the other rules are similar. According to the mining results, it can help university libraries establish a more reasonable collection layout, improve the utilization rate of library collection resources, and scientifically help libraries do a better job in book recommendation.

In order to verify the operation efficiency of the improved algorithm, a comparative experiment is carried out on FUP algorithm, SFUA algorithm and NFUP algorithm. Because FUP2 algorithm is equivalent to FUP algorithm

C_{DB}^{1}

Items	TID	Support
I_1	T1, T2, T3, T5, T6, T8	6
I_2	T1, T2, T3, T6, T7, T8	6
I_3	T2, T4, T5, T7, T8	5
I_4	T1, T2, T3, T4, T5, T6, T7, T8	8
I_5	T1, T3, T6, T8	4
I_6	T3, T5,T8	3

C_{db}^{1}

Items	TID	Support
I_1	T2, T3, T4, T5	4
I_2	T1, T2, T3, T5	4
I_3		
I_4	T1, T2, T4	3
I_5	T2, T3, T4	3
I_6	T4	1

L_{DB}^{1}

Items	TID
I_1	T1, T2, T3, T5, T6, T8
I_2	T1, T2, T3, T6, T7, T8
I_3	T2, T4, T5, T7, T8
I_4	T1, T2, T3, T4, T5, T6, T7, T8
I_5	T1, T3 T6, T8

L_{db}^{1}

Items	TID
I_1	T2, T3, T4, T5
I_2	T1, T2, T3, T5
I_3	T1, T2, T4
I_5	T2, T3, T4

① Statistics Dataset for frequent 1-itemset processes

support degree of L_{db}^{1} in D

Items	TID	Support
I_1	T2, T3, T5	3
I_2	T1, T2, T3	3
I_3	T2, T4	2
I_5	T3	1

1-itemset of db in (DB ∪ db)

Items	TID	Support
I_1	T1, T2, T3, T4, T5, T6, T8	7
I_2	T1, T2, T3, T5, T6, T7, T8	7

updated support degree of L_{DB}^{1} *in* db

Items	TID
I_4	0

updated support degree of L_{DB}^{1} *in* (DB ∪ db)

Items	Support
I_4	8

Figure 1: Continued.

First order frequent itemset of (DB ∪ db)

Items	TID	Support
I_1	T1, T2, T3, T4, T5, T6, T8	7
I_2	T1, T2, T3, T5, T6, T7, T8	7
I_4	T1, T2, T3, T4, T5, T6, T7, T8	8

② process of counting frequent 1-itemset (DB ∪ db)

Delete infrequent items in L_{DB}^1

Items	TID
I_1	T1, T2, T3, T5, T6, T8
I_2	T1, T2, T3, T6, T7, T8
I_4	T1, T2, T3, T4, T5, T6, T7, T8

Delete infrequent items in L_{db}^1

Items	TID
I_1	T2, T3, T4, T5
I_2	T1, T2, T3, T5

C_{DB}^2

Items	TID	Support
I_1I_2	T1, T2, T3, T6, T8	5
$I_1 I_4$	T1, T2, T3, T5, T6, T8	6
$I_2 I_4$	T1, T2, T4, T6, T7, T8	6

C_{db}^2

Items	TID	Support
I_1I_2	T2, T3, T5	3

L_{DB}^2

Items	TID
I_1I_2	T1, T2, T3, T6, T8
I_1I_4	T1, T2, T3, T5, T6, T8
I_2I_4	T1, T2, T4, T6, T7, T8

L_{db}^2

Items	TID
I_1I_2	T2, T3, T5

Frequent 2-itemsetof L_{db}^2 in (DB ∪ db)

Items	Support
∅	0

Support degree of L_{DB}^2in (DB ∪ db)

Items	TID
$I_1 I_4$	T1, T2, T3, T5, T6, T8
$I_2 I_4$	T1, T2, T4, T6, T7, T8

Second order frequent itemset (DB ∪ db)

Items	TID
$I_1 I_4$	T1, T2, T3, T5, T6, T8
$I_2 I_4$	T1, T2, T4, T6, T7, T8

(③process of counting frequent 2-itemset (DB ∪ db)

Figure 1: The process of digging frequent itemsets by using NFUP mining algorithm.

Table 3: Book borrowing records (part).

Borrowing number	Accession number	Borrowing number	Accession number
2015405031	I247.57	2016302021	D925.201
2015405032	F237.2/47	2016302022	F279.243
2015405033	F713.3	2016302023	B821-49
2015405034	F253	2016302024	I247.57
2015405035	TP311.5	2016302025	TP294.4
2015405036	TP391	2016302026	TP316
...	...	...	...

Table 4: Lending record transactions (part).

Borrowing number	Category	Borrowing number	Category
2015405031	I, H	2016302021	D, H, O, T
2015405032	F, T	2016302022	F, I
2015405033	F, O	2016302023	B, C, D
2015405034	F, *T*, O	2016302024	I, D
2015405035	T, K, J	2016302025	T, I, F
2015405036	T, I, H, B	2016302026	T, R, I
. . .	. . .	. . .	. . .

Table 5: Mining results (part).

Consequent	Antecedent	Support degree (%)	Confidence (%)
F	T	18.571	70.732
F	O	16.8	70.35
H	T	19.5	69.7
I	H	34.413	68.731
I	J	18.221	68.6
O	H	27.72	45.767
. . .	. . .	. . .	. . .

Table 6: Running schedule for the three algorithms.

Transaction volume (10000)	FUP (s)	NFUP (s)	SFUA (s)
1	6	4.7	5.1
1.5	8	5.6	6.3
2	9.7	7	8.1
2.5	15	8	10.5
3	18	11	14

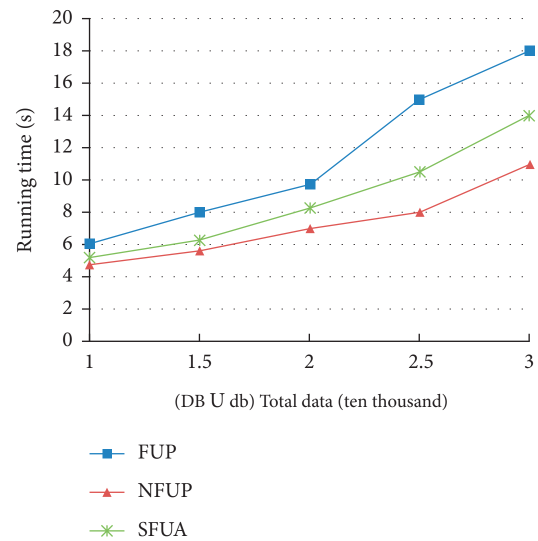

Figure 2: Comparison diagram of the experimental results.

when the database is added, so it is not used for comparison. When the original dataset DB used in the experiment is 7,000, the new dataset db is 3,000, and the dataset of (DB∪db) increases from 10,000 to 30,000, the running time of the three algorithms is shown in Table 6, the comparison of running time is shown in Figure 2. The execution time is the execution time of the updated dataset (DB∪db) when all frequent itemsets in the original database are known. From Figure 2, with the increase of transaction data, the execution time of FUP algorithm, SFUA algorithm and NFUP algorithm gradually increases, but the execution time of NFUP algorithm is shorter than that of SFUA algorithm and FUP algorithm, which has main reasons as follows:

(1) The FUP algorithm needs to scan the original dataset and the newly added one for many times. The Hash table is used to store the candidate optionset. During mining, the Hash table needs to be searched, while the SFUA algorithm scans the original transaction dataset DB once; for the newly added dataset db scans $k+1$ times. NFUP algorithm only needs to traverse the database once to obtain the transaction identifier TID of each item, and get the frequent itemset according to the transaction identifier.

(2) NFUP algorithm obtains frequent itemsets by connecting L_{K-1} and $L1$, and prunes the frequent k-itemsets before generating candidate itemsets. The amount of computation and the number of candidate itemsets of the algorithm are significantly reduced. Compared with FUP algorithm and SFUA algorithm, this algorithm is more efficient.

5. Summary and Prospect

Incremental association mining algorithm FUP solves the problem of data updating, but the algorithm needs to traverse the database many times and spend a lot of efforts dealing with the candidate itemset with geometric growth. In this study, FUP is improved. The improved algorithm NFUP uses the transaction identifier TID in the database to obtain the frequent itemsets. It only needs to traverse the database once. The candidate itemsets are obtained by connecting L K-1 and L1, so that the amount of calculation of the algorithm is significantly less than FUP. The experimental results of borrowing data in the library management system show that compared with FUP algorithm and SFUA algorithm, with the increase of the amount of transaction data, the improved NFUP algorithm improves the operation efficiency and can efficaciously help the library do a good job in book recommendation. In the next research, we can focus on the borrowing relationship of a specific subcategory (such as category TP), dig out popular books, try to dig out the relationship between majors and book categories, find out the borrowing interests of students of different majors, and recommend books according to students' borrowing habits.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Machine Vision-Based Object Detection Strategy for Weld Area

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For the noisy industrial environment, the welded parts will have different types of defects in the weld area during the welding process, which need to be polished, and there are disadvantages such as low efficiency and high labor intensity when polishing manually; machine vision is used to automate the polishing and achieve continuous and efficient work. In this study, the Faster R-CNN object detection algorithm of two-stage is used to investigate the relationship between flops and the number of network parameters on the model by using a V-shaped welded thick plate as the research object and establishing the workpiece dataset with different lighting and angles, using six regional candidate networks for migration learning, comparing the convergence degree of different Batch and Mini-Batch on the model, and exploring the relationship between flops and the number of network parameters on the model. The optimal learning rate is selected for training to form a weld area object detection network based on the weld plate workpiece under few samples. The study shows that the VGG16 model is the best in weld seam area recognition with 91.68% average accuracy and 25.02 ms average detection time in the validation set, which can effectively identify weld seam areas in various industrial environments and provide location information for subsequent automatic grinding of robotic arms.

1. Introduction

The rapid development of welding has promoted the progress of related industries. The weld seam quality directly affects the structural use performance and the product life of the product [1]. Still, the weld seam, after welding, inevitably produces defects such as spatter, weld tumor, leakage, and porosity. Manual grinding of the weld area is required to eliminate welding defects, but there are disadvantages such as subjectivity and low efficiency. And the current welding is a large V-shaped welded thick plate; an automated weld area detection is needed to be introduced to find the location of the weld area [2]. At present, the detection of the weld area at home and abroad is mainly based on traditional and deep learning methods. Traditional image weld region extraction algorithm identifies to determine the weld seam location by constructing the critical points of the image and descriptor to the image to give feature information, such as ORB (Oriented FAST and Rotated BRIEF) [3], Image Hu moment invariant features [4], and AdaBoost weak learning [5]. Laser weld area detection and 3D laser reconstruction of the weld area are widely used in current research [6]. Such methods are extracted manually, and their poor generalization and low detection accuracy are unavoidable drawbacks.

Given weld seam forming results from the nonlinear formation of multiple welding parameters, convolutional neural networks (CNN) with nonlinear properties are also gradually applied to the welding industry [7], including object detection of weld seam areas. The mainstream object detection methods are mainly divided into one-stage detection algorithms represented by SSD and YOLO series based on regression analysis and two-stage detection algorithms defined by Faster R-CNN series based on candidate regions according to the detection process [8]. The former detection algorithm pursues more speed, while the latter also pursues more accuracy.

Although various object recognition methods have achieved significant results in workpiece recognition, the V-shaped weld plate workpiece samples belong to a small number of instances, which cannot meet the deep network training requirements, and there is a lack of weld seam region extraction algorithms under the few-sample weld plate workpiece. For V-shaped weld plate workpiece, such few-sample data contains very little labeled data, mainly based on the traditional classical mature object detection method, using migration learning few-sample learning strategy [9]; based on fine-tuned migration learning of the implementation of the whole system, large-scale dataset for learning the source domain model used the model parameters to initialize the object domain model, and later on, the small-scale workpiece dataset is used for fine-tuned recognition. For the accuracy of weld seam detection, the Faster R-CNN network in the two-stage model is applied as the object recognition framework. The fine-tuned migratory learning of the learning source domain is performed using the VGG16 network. It is also tested in the test set with an accuracy rate that meets the needs of industrial use.

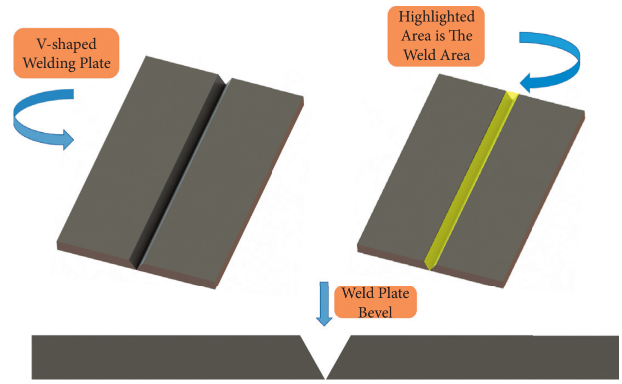


Figure 1: Diagram of the CAD model of the welded plate and the area of the weld.

2. Object Detection of Weld Seam with Few Samples

2.1. Creation of Weld Area Dataset. Migration learning of the network model is performed on the dataset ImageNet, and the Intel RealSense D435i RGB-D camera is used to capture the V-shaped weld plate workpiece with weld seam, and each view of the weld plate workpiece is shown in Figure 1. Using the eye-in-hand calibration strategy [10] to find the coordinate conversion relationship, as shown in Figure 2, the coordinates of the weld area are converted to the robot coordinates under the robot coordinates to realize the vision-based automated welding and grinding work [11].

Collect images of weld plate workpieces under backlight, normal light, and multiple angles, 1000 images in total. In order to improve the network feature learning and training speed, the image size is adjusted to 400×300 pixels. In order to learn the workpiece features at each angle and improve the network overfitting phenomenon [12], for high-frequency images under unbalanced lighting, different variance values and Gaussian filter noise with Gaussian kernel are added to them, and the data enhancement scheme of a random level, pretzel noise attack, arbitrary angle rotation, and random clipping is used to expand the dataset to 5000 samples [13] because the workpiece samples are few samples' data. Following the image data format of the neu-dataset (this is a dataset of steel plate surface curves produced by Northeastern University in China), the LabelIme annotation tool is used to export to XML, ensuring that each annotated border has only one weld feature. As shown in Figure 3, 80% of the images from the dataset were randomly selected as the training set, and 10% of the validation and test sets were divided, respectively.

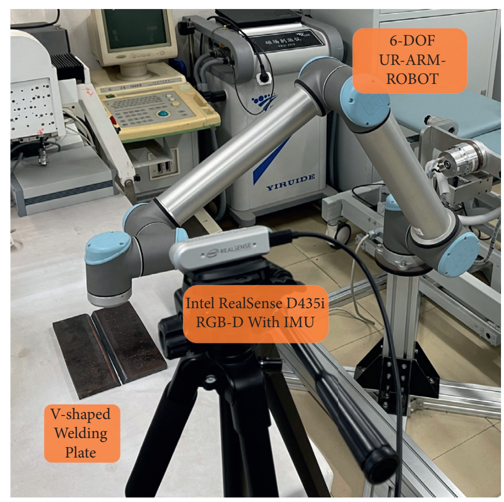


Figure 2: Diagram of welding plate, robot arm, and camera.

2.2. Migration Learning Model Building Based on Welded Plate Workpiece Dataset. The Faster R-CNN [14] in the two-stage model is used to build a workpiece-oriented object recognition network with fewer samples, using the pre-trained weights and bias information on the ImageNet dataset, freezing all parameters except the fully connected layer, and modifying the Softmax classifier to train the weld seam features of the weld plate workpiece. A simplified schematic of the network structure is shown in Figure 4.

The network model uses shared convolutional layers to extract weld region image conv features' map [15]. The network model uses a shared convolutional layer to extract the weld region image feature map, which is fed to the RPN (Region Proposal Networks) and the ROI (Region of Interest), respectively. The feature extraction layer consists of 13 convolutional layers, 13 ReLu activation layers, and four pooling layers; the RPN network determines whether the feature map belongs to the foreground or background by the Softmax classifier, where the RPN works as shown in Figure 5.

A 3×3 mask is used to slide the window motion on the feature map, and the position of the mask center corresponding to the original map is used as the center point (Figure 5(a)). Nine anchors with different scale aspect ratios are generated in the feature map (Figure 5(b)), and each anchor is assigned to the corresponding class label (positive label: foreground weld area and negative label: background area). The border regression algorithm obtains the weld area bounding box values and output to the ROI pooling layer for dimensionality reduction. The input of the ROI pooling layer is the feature map generated after the last convolution layer and the candidate region box are generated by the RPN layer,

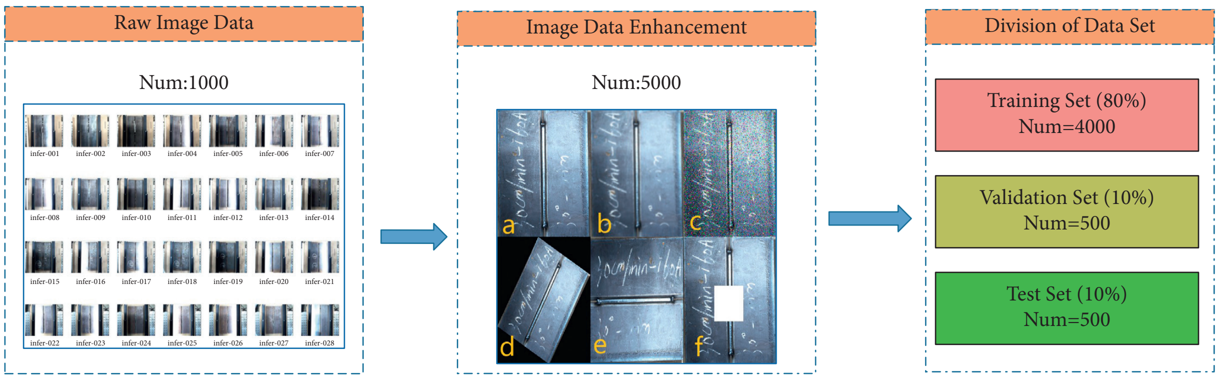


FIGURE 3: Image data enhancement: (a) original image, (b) Gaussian filtered image, (c) image with 'salt and pepper,' (d) image with random rotation, (e) image with random flap, and (f) image with random cut.

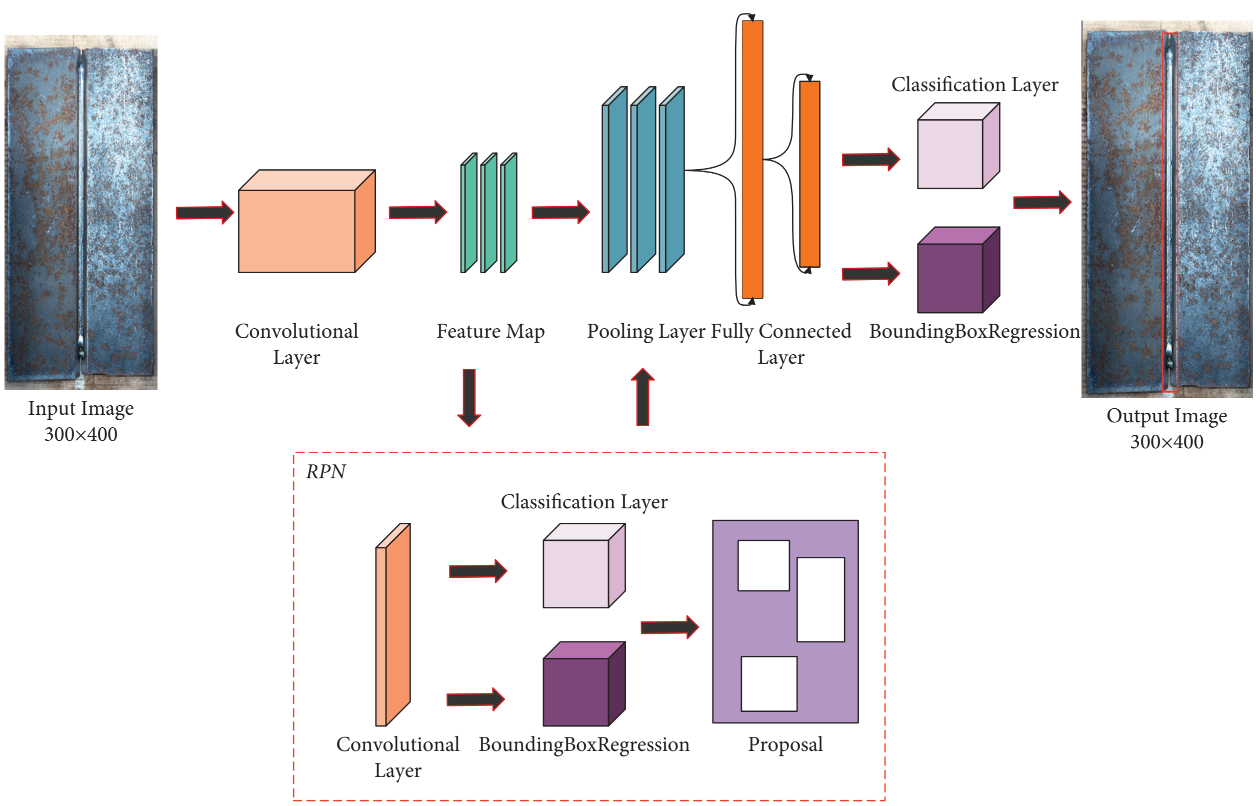


FIGURE 4: Schematic diagram of Faster R-CNN network structure.

and the final output is the ROI feature map. Finally, the fully connected layer and the Softmax classifier determine whether the candidate region is the weld region and output the exact location of the bounding box [16].

Six pretrained convolutional neural networks VGG16 [17], VGG19 [18], Googlenet [19], Resnet50 [20], Alexnet [21], and Lenet [22] on the neu-dataset are used as RPNs for migration learning so that the Faster R-CNN model first obtains the underlying feature weights of the images and then migrates the learning of these feature information to the task of weld region recognition, achieving the goal that the model can recognize accurate weld regions with a small number of artifacts.

Initial training was conducted using SGD (stochastic gradient descent) with learning rate set to 0.1, momentum factor set to 0.9, maximum Epochs set to 30, and dropout set to 0.1; the six feature region candidate networks were trained in turn, respectively. During the training process, the loss function L is as in equations (1), (2), and (3):

$$\mathbf{L}(\{\mathbf{p_i}\},\{\mathbf{u_i}\}) = \frac{1}{\mathbf{N_{cls}}}\sum_{\mathbf{i}}\mathbf{L_{cls}}(\mathbf{p_i},\mathbf{p_i^*}) + \lambda\frac{1}{\mathbf{N_{reg}}}\sum_{\mathbf{i}}\mathbf{p_i}, \tag{1}$$

$$\mathbf{L_{cls}}(\mathbf{p_i},\mathbf{p_i^*}) = -\log[\mathbf{p_i}\mathbf{p_i^*}] + (1-\mathbf{p_i})(1-\mathbf{p_i^*})], \tag{2}$$

$$\mathbf{L}_{reg}(\mathbf{t_i},\mathbf{t_i^*}) = \mathbf{R}(\mathbf{t_i}-\mathbf{t_i^*}), \tag{3}$$

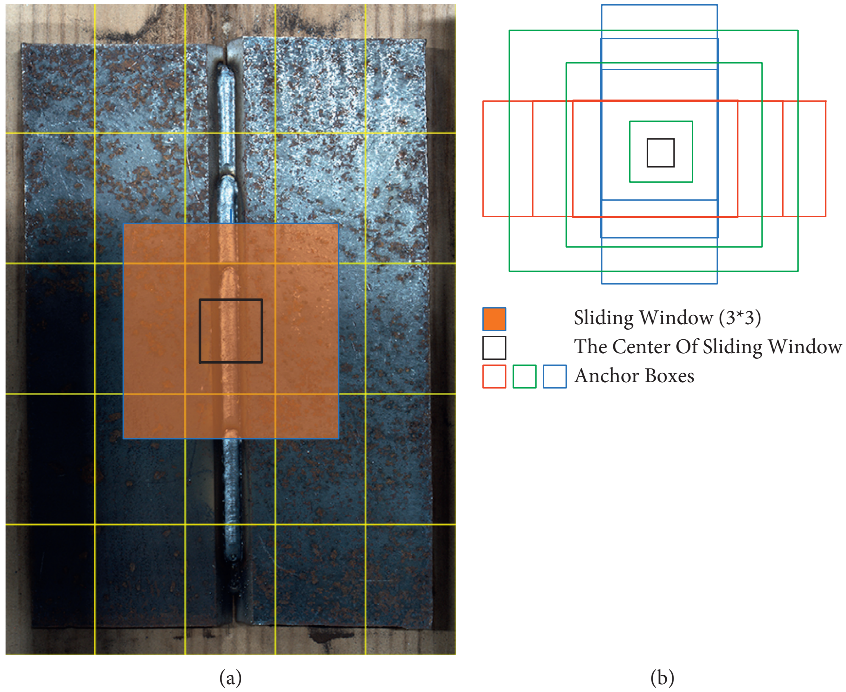


Figure 5: Sliding window diagram.

where $\mathbf{t_i} = (\mathbf{t_x}, \mathbf{t_y}, \mathbf{t_w}, \mathbf{t_h})$ is the coordinate value and bias of the bounding box, $\mathbf{t_i}^*$ denotes the predicted actual coordinate value and bias, $\mathbf{N_{cls}}$ is the number of classification samples, $\{\mathbf{P_i}\}$ and $\{\mathbf{u_i}\}$ are the output values, $\{\mathbf{P_i}\}$ denotes the predicted probability of the weld region, and $\mathbf{P_i}^*$ denotes the anchor point discriminant value, and when its value is 1, the anchor point is a positive label indicating identification to the weld region [23]; when its value is 0, it is a negative label indicating identification to the weld plate region. $\mathbf{L}_{\text{cls}}$ denotes the classification layer loss function, and $\mathbf{N}_{\text{reg}}$ denotes the number of regression samples. Since L1 loss has high noise immunity and insensitivity to numerical fluctuations compared with L2 loss, it can achieve better results in finding the border value of the target classification, so L1 loss is used, as shown in (1) [24]:

$$R = \text{smooth}_{L1}(x) = \begin{cases} 0.5\mathbf{x}^2 & |\mathbf{x}| < 1 \\ |\mathbf{x}| - 0.5 & \text{others} \end{cases}. \tag{4}$$

Iterative training and testing were performed on professional graphics workstations with the training and testing environments, as shown in Table 1.

2.3. Evaluation Method for the Performance of Weld Area Identification Models. Precision P (Precision), Recall R (ReCall), and Average Precision AP (Average Precision) [25] are used as evaluation metrics for object detection in the weld area to assess the degree of merit of the model. The calculation is shown in equations (5), (6), and (7):

$$P = \frac{TP}{TP + FP}, \tag{5}$$

$$R = \frac{TP}{TP + FN}, \tag{6}$$

$$AP = \int_0^1 P.R.\mathrm{d}R. \tag{7}$$

In (2), the larger the AP is, the better its recognition of weld regions is. TP is the number of correctly classified positive samples, FP is the number of incorrectly classified positive samples, and FN is the number of incorrectly classified negative samples. For each identified weld region, the identification score of the weld region is expressed as a confidence level. The precision-recall curves are plotted [26]. The precision responds to how accurately it predicts the positive samples, the recall responds to how well the classifier covers the positive samples, and the average precision is the integral of the precision-recall curve.

This study ensures that different candidate zone networks are tested and analyzed in a unified hardware-software environment to ensure a consistent FLOPS (Floating-Point Operations Per Second) [27]; the metric is used to measure to estimate the execution performance of the computing platform. The number of parameters of the RPN is only related to the network structure, and the memory occupation of the model is approximately four times the memory occupation of the number of parameters. The

Table 1: Hardware parameters and deep learning environment.

Environment name	Version
Operating system	Ubuntu16.04 LTS
CPU	Intel (*R*) Core (TM) i9-12900 K @5.0 GHz
GPU	GeForce RTX 3090 ×2
RAM/ROM	Fury DDR4 2666 MHz 16 *G* ×2/2T 970 Evo Plus M.2
Deep learning framework/*Python*	Pytorch stable (1.9.1)/3.81
IDE	Pycharm for professional 2020.02
CUDA	11.4
cuDNN	8.1

number of parameters [28] for the convolutional and fully connected layers is calculated as shown in equation (8), (9), and (10):

$$ParasConv = n \times (h \times w \times c + 1), \tag{8}$$

$$\text{ParasFull} = \text{Weight}_{\text{in}} \times \text{Weight}_{\text{out}}, \tag{9}$$

$$\text{ParasNum} = \sum_{1}^{i} \left(ParasConv_i + \text{ParasFull}_i \right), \tag{10}$$

where c is the number of input channels, n is the number of output channels, h is the height of the convolutional layer, and w is the width of the convolutional layer. The pooling layer does not need to calculate the number of parameters. A low number of parameters prevents the model from reaching the weld area features, making the model underfit. A high number of parameters will cause the model to occupy too much memory space, and the memory access cost (MAC) will increase. To measure the model complexity of the candidate area network, the number of floating-point operations, FlOPs, is introduced.

To compute FLOPs, this study assumes convolution is implemented as a sliding window [29] and that the nonlinearity function is computed free. For the specified convolution kernel, it is calculated as in equation (11).

$$\text{FLOP}s = 2HW\left(C_{\text{in}} K^2 + 1\right) C_{\text{out}}, \tag{11}$$

where H, W, and C_{in} are height, width, and number of channels of the output feature map, K is the kernel width (assumed to be symmetric), and C_{out} is the number of output channels [30]. For fully connected layer, it is calculated as shown in (7):

$$\text{FLOP}s = \left(2D_{\text{in}} - 1\right) D_{\text{out}}, \tag{12}$$

where D_{in} is the input dimensionality and D_{out} is the output dimensionality. The performance parameters of each RPN are shown in Table 2.

3. Result and Analysis

3.1. Recognition Results' Weld Areas by Different Feature Extraction Networks. This study uses a V-shaped welded steel plate with dimensions of 30.00 cm × 17.00 cm × 0.50 cm, a V-shaped opening angle of 45°, and a weld seam formed in the following welding parameters: the steel plate material is mild steel Q215, the welding method used is melt electrode gas metal arc welding (GMAW) and multilayer multipass welding, the shielding gas is argon, the welding current is 200 A, the welding wire diameter is 2 mm, and welding speed is 2 mm per second. By the recognition effect of the weld seam on the same V-shaped welding plate, the convolutional neural network with the best effect is selected as the RPN, and the model is fine-tuned on this basis for comparative analysis of the recognition of the weld seam in different work scenarios.

Ensuring consistent FLOPS, the network accuracy images and training loss images are plotted using the initial training parameters set in Section 2.2, using six different RPNs in the training and validation sets, respectively. The result is shown in Figure 5.

As shown in Figure 6, the statistical training results obtained by changing different RPNs in the Faster R-CNN model are shown in Table 3, where AP (%) - *T* is the average precision of the training set and AP (%) - V is the average precision of the validation set.

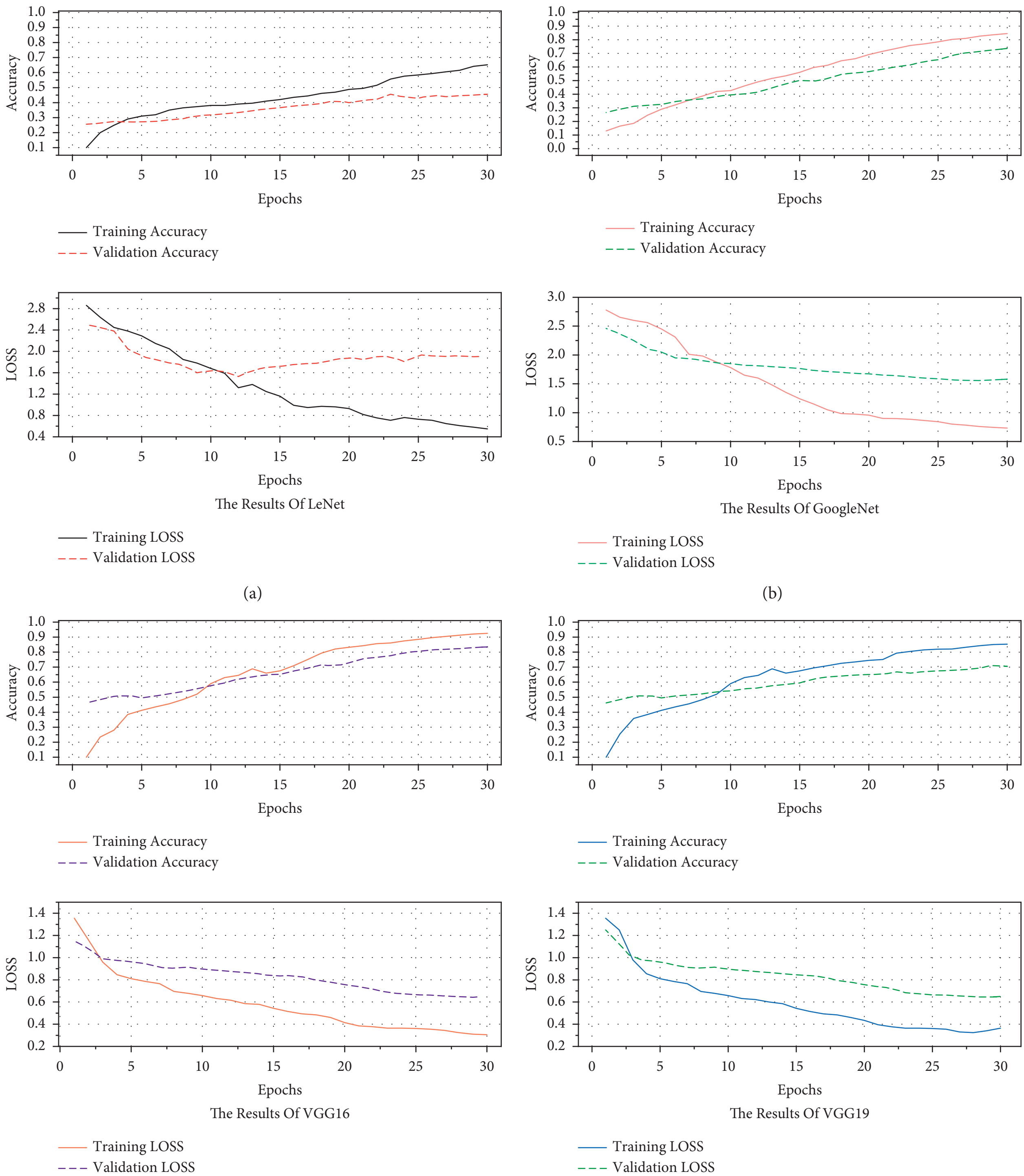
100, 200, 300, 400, and 500 different weld plate images are taken from the weld plate part test set as input images, and their average detection times are recorded to evaluate the operational efficiency of the algorithm (Figure 7).

Resnet50 is used as the RPN with the highest average accuracy in the training and validation sets, and the fraction of recognized weld areas is up to 94.34% (Figure 8(d)). The Resnet series network provides a shortcut connection mechanism, which ensures a reasonable recognition rate even if the network depth of Resnet50 is 50 layers and the number of layers.

The increase in the number of layers leads to flops 4GFLOPs. Resnet50 average detection time is 92.03 ms. Among them, when Alexnet is used as RPN, the flops are 727MFLOPs, and the average detection time consumes the shortest 18.02 ms because the number of convolutional layers is 5, the network learning effect is not as good as the deep network Figure 8(b), and its average recognition accuracy is 75.50% (Figure 8(a)). In the training process, Alexnet accuracy function and loss function gradually converge, and the loss function curve in the validation set fails to approximate the loss function curve in the training set, so the result weld candidate box has more rear view parts in the weld region candidate box (weld plate region). VGG19 can identify the weld area more completely (Figure 8(f)) with 20GFLOPs and 20,483,904 parameters, as shown in Table 2, resulting in a memory occupation of 548 M and a

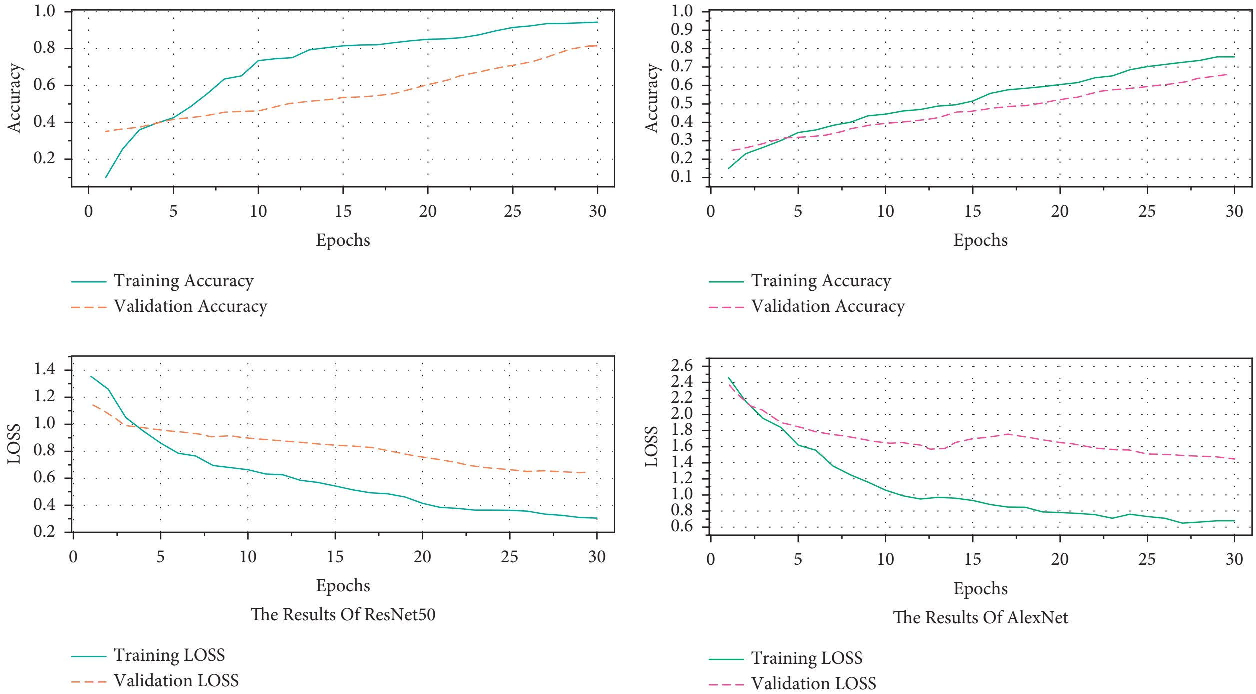
Table 2: Performance parameters of RPNS.

Region proposal networks	Number of network layers	Number of parameters/memory size (MB)	Flops
VGG16	16	62,378,344/(528 MB)	16 GFLOPs
VGG19	19	20,483,904/(548 MB)	20 GFLOPs
Resnet50	50	25,000,000/(78.1 MB)	4 GFLOPs
Alexnet	11	60,965,128/(233 MB)	727 MFLOPs
Googlenet	22	6,990,270 (51 MB)	2 GFLOPs
LeNet	7	431,080/(0.07 MB)	2.32 MFlops



(a) (b) (c) (d)

Figure 6: Continued.



(e) (f)

FIGURE 6: Training curves of different RPN. (a) Training curves of LeNet, (b) Training curves of GoogleNet, (c) Training curves of VGG16, (d) Training curves of VGG19, (e) Training curves of ResNet50. (f) Training curves of AlexNet.

TABLE 3: Six types of RPN network AP values.

RPN	VGG16	VGG19	Resnet50
AP (%) -T	91.55	85.34	94.34
AP (%) -V	86.45	70.05	84.5
RPN	Alexnet	Googlenet	LeNet
AP (%) -T	75.50	84.55	65.23
AP (%) -V	66.50	73.60	45.60

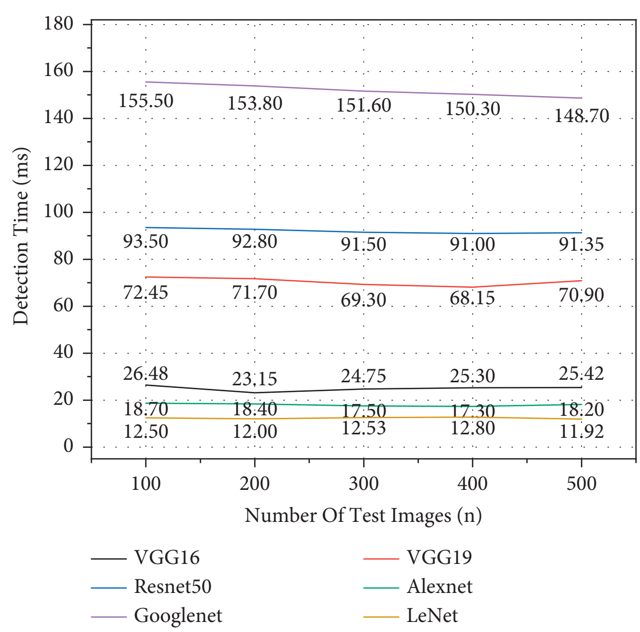


FIGURE 7: Runtime with different numbers of test sets.

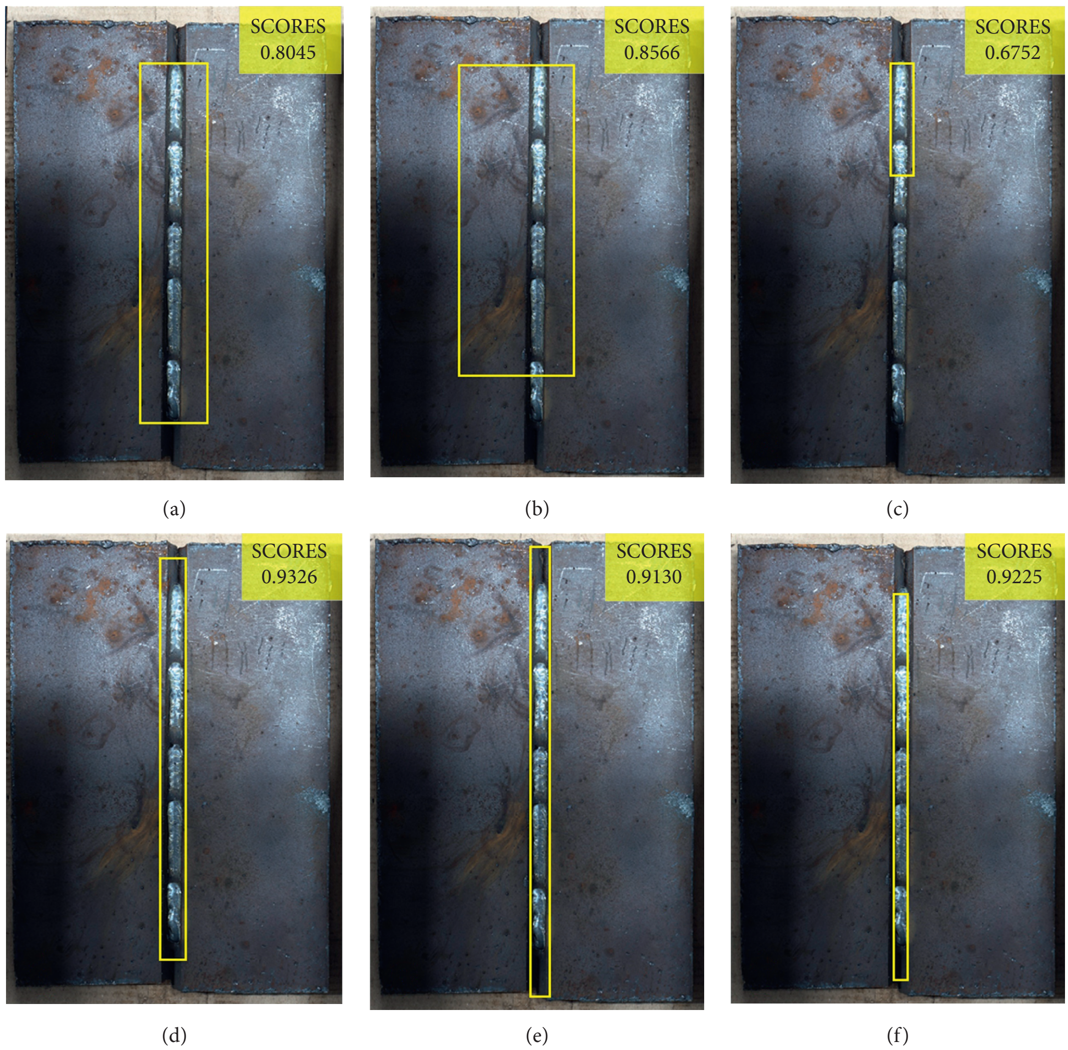


Figure 8: Recognition results of different RPN models for the same weld plate (comparison of six different RPNs using the same weld plate workpiece): (a) Alexnet, (b) Googlenet, (c) Lenet, (d) Resnet50, (e) VGG16, and (f) VGG19.

bloated model with a detection time of 70.50 ms. The worst performance is LeNet, which has the shortest average detection time, occupies 2.32 MFlops, and has the smallest number of parameters among the six networks.

Because its network layer is 7, it cannot learn the weld region's image features in-depth and is more suitable for dealing with scenarios requiring shallow network work and can only identify some features in the weld region under this study (Figure 8(c)).

The average accuracy of VGG16 is slightly lower than that of Resnet50 at 91.55%. Since VGG16 uses several consecutive 3x3 convolutional kernels instead of the larger convolutional kernels in Alexnet compared to AlexNet, for a given receptive field, the performance of the small convolutional kernels with stacking is better than that of the large convolutional kernels because the multilayer nonlinear layers can increase the network depth to ensure learning of more complex pat-terns, the flops' value of VGG16 is lower than that of VGG19 in the same series, and the number of parameters is increased to ensure the learning effect and reduce the memory occupied memory space. The average elapsed time is lower, only 25.02 ms, and the confidence level of the identified weld region is up to 91.30%, and the entire weld region is framed (Figure 8(e)). Therefore, the Faster R-CNN model based on the VGG16 candidate region network is selected as the model to identify the weld region.

3.2. Optimization of Models. As shown in the Result of VGG16 in Figure 5, the Faster R-CNN based on VGG16 for weld area recognition object detection network achieves 91.55% accuracy in the training set, and the accuracy in the validation set cannot converge to the same level as the test set. And in order to reduce the loss value to convergence in both training set and test set, different learning rates are chosen to be adjusted, and different numbers of Epochs are added, and Mini-Batch is more suitable for fewer sample data set models, so the optimization of the model is added on this basis. In order to make a comparison with the initial training parameters in Section 2.2, the size of the Mini-Batch is chosen to be 128. the time cost of training. As shown in Table 4.

Table 4: Mini-Batch in VGG16.

Epoch	Mini-Batch training accuracy (%)	Validation accuracy (%)	Mini-Batch training loss	Validation loss
1	38.52	45.85	1.36	1.28
5	79.20	55.98	0.76	0.95
10	88.10	64.50	0.51	0.84
15	90.56	78.64	0.45	0.80
20	92.35	82.65	0.34	0.76
25	93.48	83.62	0.31	0.71
30	93.85	85.62	0.28	0.69

Table 5: Accuracy results of training models with different numbers of Epoch and different learning rates.

Learning rate	Epochs: training accuracy (validation accuracy) (%)						
	30	35	40	45	50	55	60
0.1	89.57 (81.63)	91.18 (82.34)	93.88 (83.65)	92.03 (84.55)	92.86 (85.64)	92.01 (84.63)	91.61 (83.52)
0.01	93.85 (84.56)	94.10 (86.78)	94.33 (87.12)	94.85 (89.73)	95.17 (91.23)	94.01 (90.55)	93.51 (89.77)
0.001	94.56 (86.64)	94.84 (88.50)	95.25 (89.66)	95.36 (90.16)	95.66 (92.38)	93.83 (90.56)	92.84 (89.71)
0.0001	95.75 (89.31)	95.89 (89.65)	95.91 (91.68)	95.85 (92.36)	95.93 (92.45)	94.59 (91.63)	93.88 (91.09)
0.00001	94.79 (88.71)	94.97 (89.08)	95.48 (90.16)	95.12 (91.74)	95.25 (91.65)	94.77 (91.02)	93.87 (91.87)

The plasticity of the VGG16-based Faster-RCNN weld region detection model is verified by adjusting different Epoch and learning rates, and then, the optimal network model is obtained, and the results are shown in Table 5.

In Table 5, using VGG16 as RPN for migration learning at different learning rates, the model's accuracy gradually improves with increasing training times and starts to converge in both the training and validation sets. Reducing the learning rate of the network model can effectively improve the average accuracy of the overall model network at the same number of training sessions. Among them, when the learning rate is 0.1 and 0.01, the network converges very slowly, increasing the time to find the optimal value and not achieving optimal training accuracy. When the learning rate is 0.0001 and Epochs is 30, the accuracy of the network on top of the training set reaches 95.75%, and as Epochs keep increasing, the training accuracy keeps converging, but the growth is slow, and the average accuracy of 45 iterations is lower than before, and if we use continued iterative training, it will increase the algorithm is time complexity, but it does not bring noticeable improvement of training accuracy. When the learning rate is 0.00001, the effect is not as good as the learning rate of 0.0001 because the model hovers around the optimal value, does not converge, and appears to be overfitting. Each learning rate showed an overall decreasing trend after Epochs of 40, which was due to overfitting the network during training. Therefore, in this study, VGG16 is used as the RPN, and the Faster R-CNN with two-stage is trained on the weld plate workpiece dataset, keeping other parameters in Section 2.2 unchanged. The batch is changed to a Mini-Batch of size 128, and at a learning rate of 0.0001 and Epochs of 40 times, the 500 weld plates in the test set were used as the target for the Precision-Recall curve. The initial accuracy threshold was set to 0.8500 using a non-extreme suppression mechanism. The point of [0, 0.8500] was decremented in the Recall interval. The model determined the results more excellent than this threshold as positive samples and those less than this threshold as negative samples. As can be seen in Figure 9, as the entry is gradually reduced, more and more weld samples are predicted to be positive, and the curve reaches the (1, 0) coordinate point, indicating that the target detection model can identify the weld seam in the image data as a positive sample. In equation (7), the area enclosed by the curve and the coordinate perimeter is AP. As shown in Figure 9, the area surrounded by its X- and Y-axes occupies almost the entire coordinate axis area, indicating the strong recognition performance of the model.

As shown in Figure 10, the color is similar to that of the weld plate workpiece at different angles and working environments, but the network can also identify the weld area of both weld plate workpieces with a score above 90%. As shown in Figure 11, the complex industrial environment with different angles and each large field of view is used for recognition, and there are multiple weld parts in the image, the model network is able to recognize the complete weld area, and some smaller weld areas in the lower-left corner of the image can also be accurately recognized.

In Figure 12, the model is tested in this study by placing it in different working scenarios. Figures 12(a), 12(b) and 12(c) show the weld target detection recognition results at different angles. It can be seen that the recognition accuracy is almost always above 90% and is close to the training accuracy when trained on the training set. The material color in the background of the recognition scene is similar to that of the foreground weld plate, and the object detection network can still accurately frame the weld area's location. Figures 12(d), 12(e) and 12(f) show the effect of weld target detection with the influence of the side light source at a normal overhead angle, which can identify the weld area more completely and obtain an accuracy of about 92%. Figures 12(g), 12(h) and 12(i)

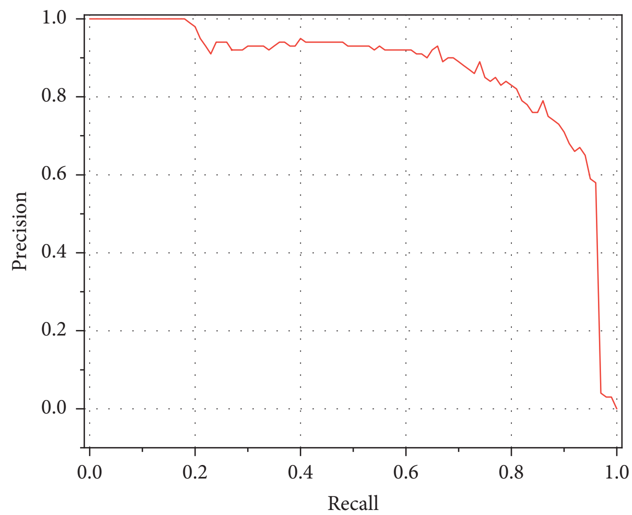


Figure 9: Precision-Recall curve based on VGG16.

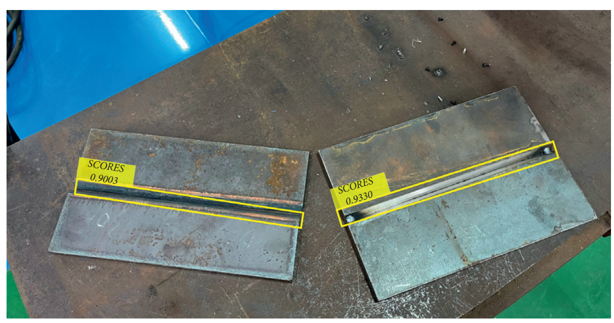


Figure 10: The recognition effect of tilt angle.

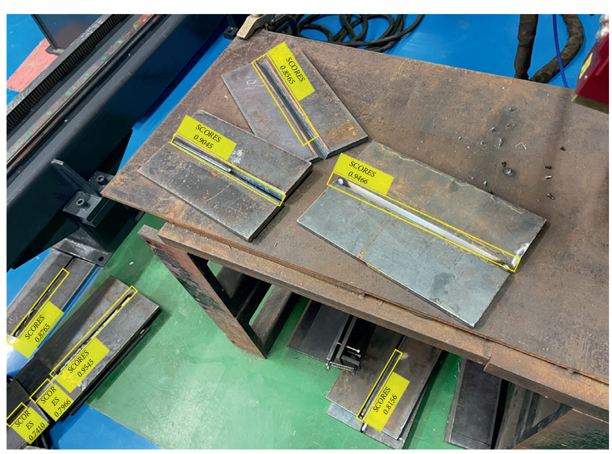


Figure 11: Multiple weld plate workpiece identification effect.

show the weld seam target detection results with laser interference and multiangle recognition. The target detection network can still frame the weld seam in a noisy environment, with a maximum recognition accuracy of 93.17% with laser and multiangle interference. The experimental results in Figure 12 show the robustness of this neural network model for the identification of weld areas in different working environments.

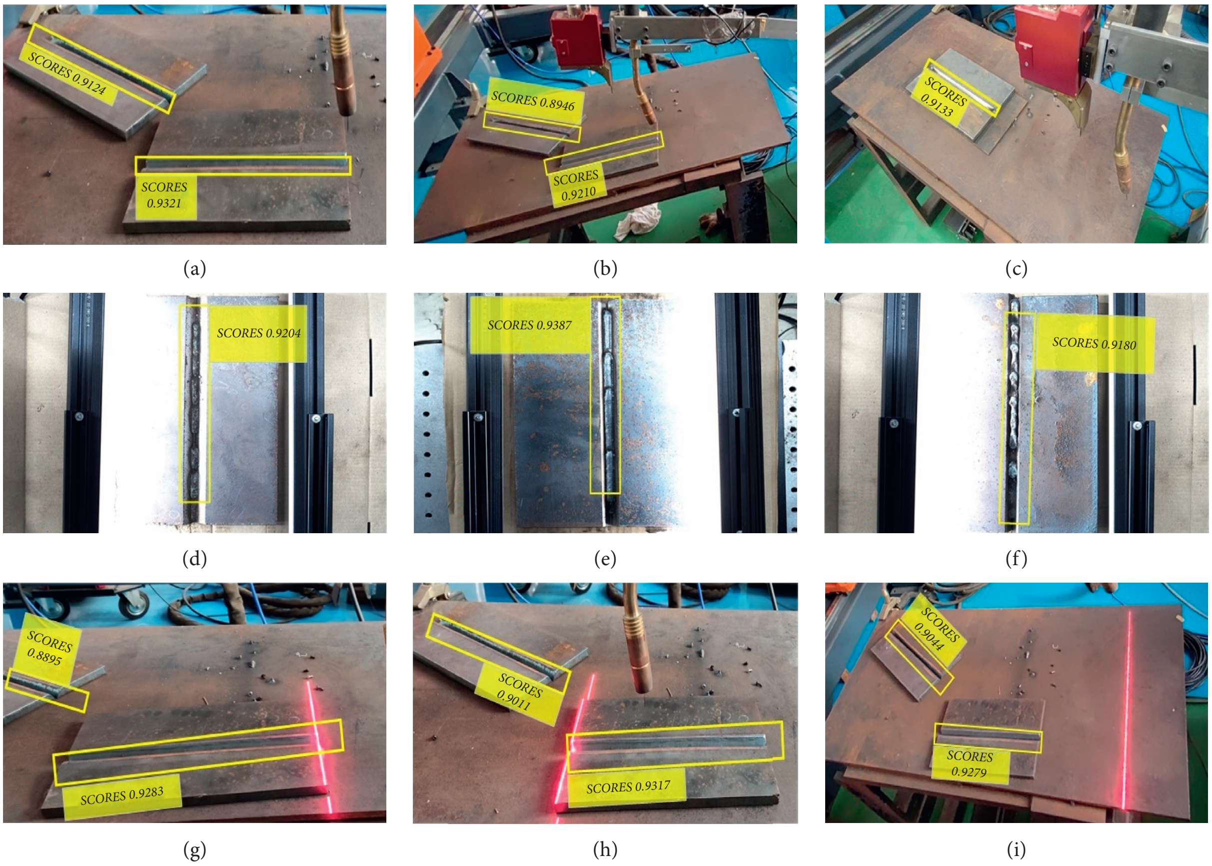


Figure 12: Multiangle and multienvironmental weld seam recognition effect.

4. Conclusion

The six networks LeNet, Resnet50, Googlenet, VGG16, VGG19, and Alexnet are selected as the RPN of the Faster R-CNN model for training using the migration learning method, and the recognition performance of the six Faster R-CNN models with migration learning is compared and analyzed, and the following conclusions can be drawn:

(1) Faster R-CNN based on VGG16 weld region detection effect is the best, when the model learning rate of 0.01 training times for 30 times, the model in the training set average accuracy of 91.55%, and the validation set accuracy of 86.45%. In the test set average detection time of 25.02 ms, in order to speed up the convergence of the network training process. In order to speed up the convergence of the network training process, the Batch is changed to Mini-Batch size set to 128, which can further improve the accuracy of the model in the training and validation sets, and the loss function convergence is reduced.

(2) When the learning rate is 0.0001, the accuracy decreases with the increase of Epochs in the training set, which is an overfitting phenomenon. After Epochs is 40, the model accuracy grows slowly to prevent the increase of time complexity; this study adopts the learning rate of 0.0001, Mini-Batch is 128, Epochs is 40 training parameters, and the identified network is applied to weld area recognition; as shown in figure, the recognition accuracy and breadth can meet the industrial requirements. The model is also able to accurately frame the weld seam in a mixture of multiplate conditions, multiangle welding conditions, and laser light source interference.

(3) From the point of view of real time, when the target detection model uses a VGG16 convolutional neural network as RPN, it can meet both the requirements of detection accuracy and detection time. The target detection model can achieve industrial recognition efficiency for weld area extraction in different environments, whether the recognition effect is under the ideal viewpoint or weld recognition effect under a complex environment. The industrial requirements for real time can be met.

Data Availability

All data are from laboratory collection and self-consumption.

Conflicts of Interest

All authors have no conflicts of interest and acknowledge the order of attribution.

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Research Article

Evaluation of Accounting Data of Water Company Based on Combination Model

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Driven by the dual effects of artificial intelligence and accounting transformation, it has become one of the research hotspots of accounting intelligence in China to replace accountants with computers to make professional judgments and automatically evaluate accounting. On the basis of summarizing and analyzing the research status in the field of intelligent accounting, the realization path of intelligent accounting in water companies is put forward in this paper. By introducing the improved Apriori learning algorithm based on Boolean mapping matrix, intelligent data mining is carried out for evaluation of water accounting. With the help of the improved attribute inductive learning algorithm, the corresponding relationship between the original water consumption attribute and the water right transaction is mined and output. In addition, with the help of forward reasoning in inference engine technology, the computer intelligent data evaluation function is realized. Finally, the functional architecture of accounting system of the water company is designed, which provides reference for the development and application of intelligent accounting system, and explores a new path for the integration of accounting and intelligent algorithms.

1. Introduction

After more than 40 years of development, China has basically realized the automation of accounting books and statements processing, but the accounting personnel's professional judgment is always indispensable in the preparation of accounting vouchers, which leads to the stagnation of accounting automation in China. With the continuous development of artificial intelligence in the accounting industry, the research and development of intelligent accounting system with self-learning and the replacement of accountants by computers for professional judgment and automatic preparation of accounting vouchers have become the key research field of accounting [1]. The key to realize the intelligentization of accounting is to make the computer have the ability of autonomous learning, intelligent judgment, and reasoning in unsupervised mode. With the help of accounting rules automatically acquired by intelligent learning algorithm, it can analyze and judge economic business and compile accounting vouchers. Because the computer does not have the function of self-learning, and when the accounting rules change, the accounting voucher template needs to be changed manually, even if the financial robot based on RPA (Robotic Process Automation) technology is not intelligent accounting either. In essence, the financial robot is a computer based on predesigned fixed rules and processes [2] and a computer program that helps human beings to complete standardized work with fixed rules and high repeatability by simulating manual operation of computers.

Water enterprises belong to the water rights entity, which is the main body of water resources development and utilization. Water-related businesses include water storage, water treatment, water supply, and water trading [3]. Because of the various types of business, large scale and large water flow, water enterprises are representative in the process of realizing intelligent accounting. In water enterprises, establishing water accounting subjects, accounting water accounting business, formulating water accounting statements, expanding the application of existing water accounting framework of water rights entity to specific water users, and establishing corresponding accounting system can verify that the existing framework of water rights entity is the key of current research [4].

Therefore, in this paper, Apriori improved algorithm based on Boolean mapping matrix is used to automatically mine frequent item sets from accounting voucher database, and through attribute-oriented induction (AOI) algorithm, accounting rules are learned and extracted from the original water consumption database independently, forming accounting rule base, which enables the computer to have self-learning ability in unsupervised mode. Combined with the actual operation of water enterprises, the accounting of characteristic businesses such as sewage treatment, construction, and management of water delivery facilities is carried out. While promoting the fine management of water resources, the water accounting system is improved and the connotation of water accounting research is enriched and according to the original water consumption data and accounting rule base, with the help of inference engine technology, the computer has the function of automatically compiling accounting vouchers. Finally, the evaluation of accounting data will be realized, which will help accountants transform from accounting to management-assisted decision-making.

2. Basic Accounting Theory and Accounting Basis of the Water Company

2.1. Theoretical Framework. At present, there are two representative views on the definition of accounting in China's accounting theory circle, namely, information system theory and management theory [5]. From the perspective of information system theory, water resources accounting can be defined as follows: water resources accounting is based on the stock and flow of water resources, using monetary measurement units, and standardizing according to the requirements of specific accounting assumptions and accounting principles. By adopting the methods of modern accounting, resource economics, mathematics, and asset appraisal, the economic information system provides water resources information to users of water resources accounting information regularly through accounting and supervision [6]. According to the management activity theory, water accounting is a kind of management activity applied to water industry to reflect and control the process and results of water resources circulation caused by ecological circulation of water resources.

2.1.1. Accounting Objectives. Accounting objective is the highest level of accounting theoretical structure, which is the expression of subjective consciousness under certain social and economic environment. Only by correctly understanding the influence of these factors can we study accounting objective more deeply [7]:

(1) Ultimate objective: sustainable development is the theme of world development today. Water accounting is put forward under the condition that water resources are increasingly scarce and the sustainable development and survival of human beings are threatened. Water resources accounting should take sustainable development as the ultimate goal to promote people to rationally utilize water resources.

(2) General objectives: the general goal of water resources accounting is to make rational use of water resources accounting to obtain maximum social and economic benefits. Through the establishment of water resources value system, water resources information can be provided to promote the rational allocation and utilization of water resources. The establishment of water resources value system means that the law of value can be applied to allocate water resources by market [8]. The marketization of water resources (under certain intervention) will make the utilization of water resources more reasonable and scientific.

Water supply and demand are regulated separately. Water supply is ultimately determined by the "available water in the region" module, while the demand is mainly specified by the "water demand" module [9, 10]. This separation and linear structure of demand and supply is shown in Figure 1, in which the data connection from one module to another module is indicated by arrows. For example, different data exported from the module of "Water Availability in the Region" are directly transferred to the module of "Distribution of Emissions," "Water Allocation," "River Flow Calculation," and "Groundwater Flow" [11].

2.1.2. Accounting Hypothesis. Accounting hypothesis is to limit the scope and content of accounting and make logical inference according to the objective normal situation or trend of accounting phenomenon that has not been confirmed. Due to the economic characteristics of water resources, the basic assumptions of water resources accounting should include the following points besides general accounting hypothesis [12–15]:

(1) The assumption of sustainable development: although there are many uncertainties in the economic activities of accounting subjects, the normal procedures and methods of accounting and supervision should be based on the sustainable development of accounting subjects, especially in water resources accounting. Therefore, sustainable development is the hypothetical condition of water resources accounting, which is also the fundamental constraint for us to construct the water resources accounting theory and method system.

(2) Multiple units of measurement hypothesis: water resources accounting should be based on monetary measurement. Its accounting is to supervise enterprises in the whole water resources environment. Besides monetary measurement, physical quantity indicators and words can also be used to explain their social contributions or social losses, such as

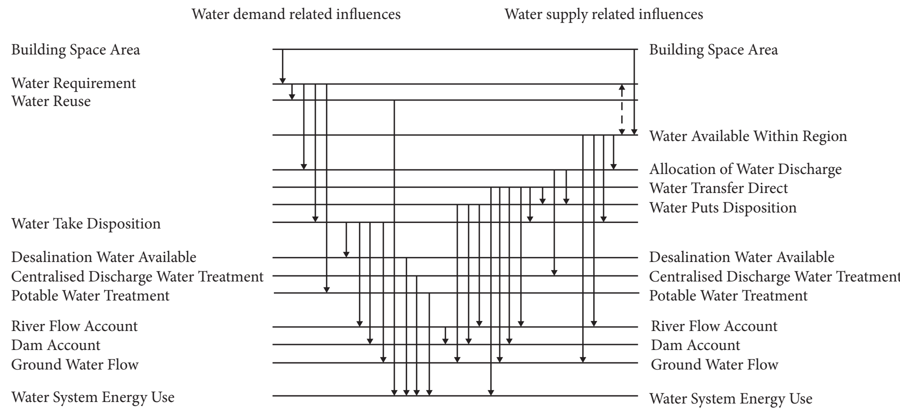

Figure 1: Module of water resources accounting.

biochemical oxygen demand, chemical oxygen content, suspended solids, and toxic substances in water pollution indicators.

(3) Multiple measurement attribute hypothesis: the assumption of multiple measurement attributes is also reflected in the fact that multiple measurement attributes should also be adopted within the monetary measurement form. Not only can historical cost, current cost, current market price, net realizable value, and future cash flow be used, but also new measurement attributes such as opportunity cost and substitution cost can be used in water resources accounting.

2.1.3. Accounting. Under the condition of clear water rights, the transformation quantity of microwater rights entity is accompanied by the changes of water quantity increase and decrease, such as water quantity acquisition or use, loss, and discharge, which is reflected in the fact that the increase or decrease of one water resources assets transformation movement is always closely related to the decrease or increase of another water resources assets transformation movement [16]. The accounting structure is shown in Figure 2.

Account setting of water resources accounting: the confirmation of water accounting elements can be based on traditional accounting element confirmation, which develops and broadens the concept connotation of traditional accounting element confirmation. The elements of water resources accounting include water resources assets, water resources liabilities, water owners' equity, water resources income, water resources expenses, and water resources profits [17]. According to the accounting elements of water resources, accounts such as water resources assets, water resources liabilities, water resources costs, water resources income, water resources profits, water resources capital, and water resources capital appreciation can be set up accordingly.

The account of water resources assets reflects the increase and decrease of water resources assets, and the account of accumulated consumption of water resources assets reflects the consumption of water resources assets [18]. "Water resources compensation payable" can be set for water resources liability accounts. The occurrence of water resources costs should be listed in the accounts of production cost, management cost, and manufacturing cost according to their different consumption and occurrence nature, and corresponding secondary accounts, such as water pollution control fee and water quality degradation fee, should be opened to reflect the various water resources costs incurred by microaccounting entities.

3. Realization of Intelligent Accounting

At present, there is a general consensus on the transformation of accounting from automation to intelligence under the background of artificial intelligence. However, most of the existing researches on intelligent accounting are focused on the impact of artificial intelligence on accounting industry and personnel, the assumption and prospect of intelligent accounting system architecture, etc. [19], and its development process is shown in Figure 3. Although some researches have studied the realization of intelligent accounting voucher preparation, the research process cannot get rid of accounting voucher template theory, accounting expert simulation theory, and assistant judgment of accountants, and most of the research results belong to the category of semiautomation or weak artificial intelligence. In addition, it is relatively rare to introduce artificial intelligence data mining algorithm into practice of water company, and it is even rarer to study the improvement and integration of machine learning intelligent algorithm and accounting information system. The results of developing practical intelligent accounting system with computer language platform are relatively few [20]. Although BP artificial neural network algorithm is theoretically introduced to explore the confirmation of accounting elements, due to the dynamic learning parameters of BP neural network and the instability of network output, the related research results cannot meet the basic requirements of accounting practice [21].

The intelligence of the intelligent accounting system is mainly reflected in the fact that the computer must have the ability of self-learning, knowledge updating, judgment

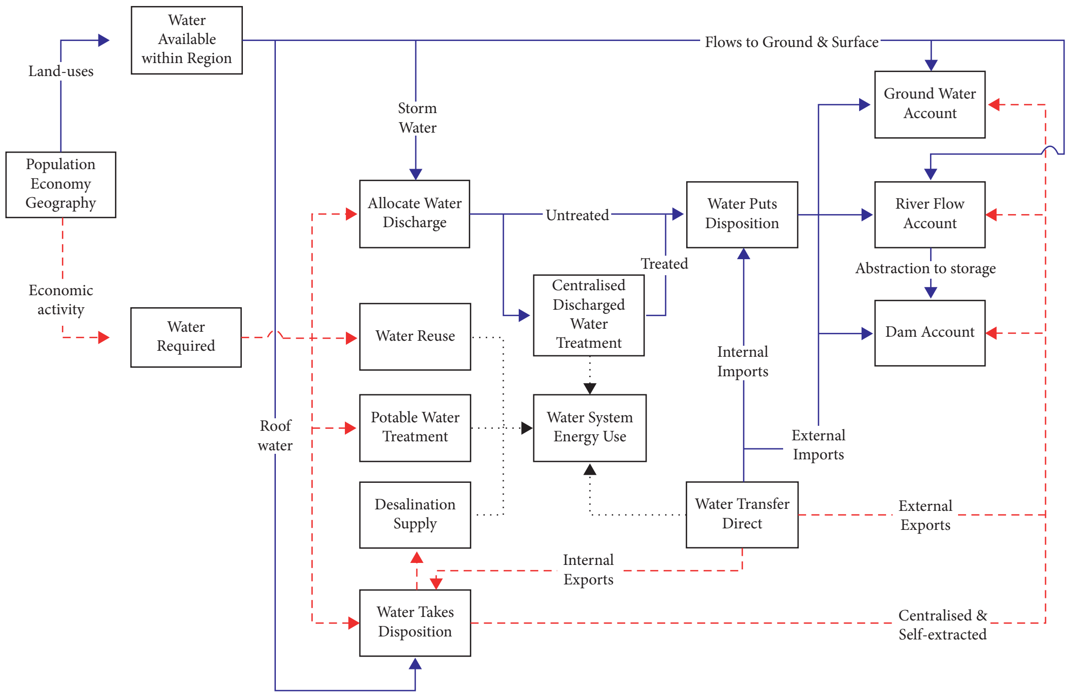

Figure 2: Structure of water resources accounting.

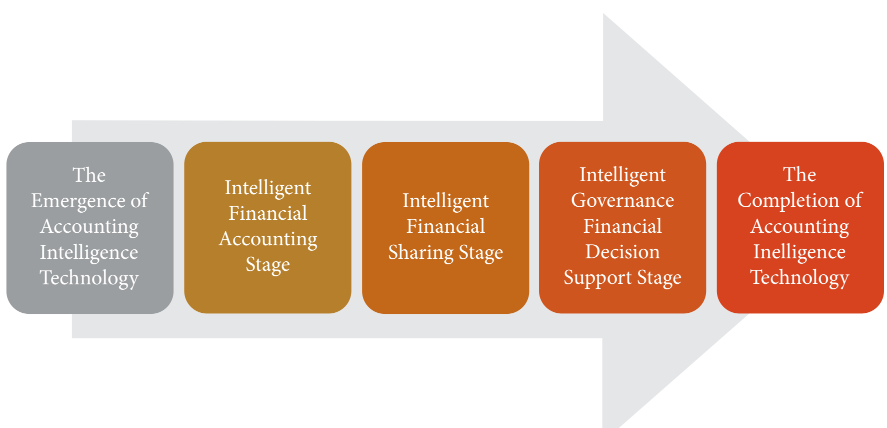

Figure 3: Development of intelligent accounting.

reasoning, and knowledge memory storage in unsupervised mode [22]. Therefore, the intelligent accounting system should have enough training samples for machine learning, on the one hand, and introduce intelligent algorithms for machine learning on the other hand, both of which are indispensable. At present, there are only accounting vouchers, account books, statements, and other related data in the mainstream accounting information system in China. The key information needed by machine learning intelligent algorithm is still blank. The core of accounting measurement is to determine the name, accounting direction, and accounting amount of the account. Different economic businesses have different impacts on accounting elements, and the combination of generated account and accounting rules will also have certain changes in different periods and different stages of the development [23].

The intelligent learning algorithm should be able to accurately mine and store the account combination rules and extract the corresponding relationship between the original voucher and the accounting voucher from the database (essentially, the corresponding relationship between the attributes and attribute values of the original voucher and the account name, accounting direction and accounting amount of the accounting voucher) [24]. In this way, the accounting system has intelligent attributes and can replace accountants to make professional judgments and automatically compile accounting vouchers, thus developing towards the direction that is shown in Figure 4.

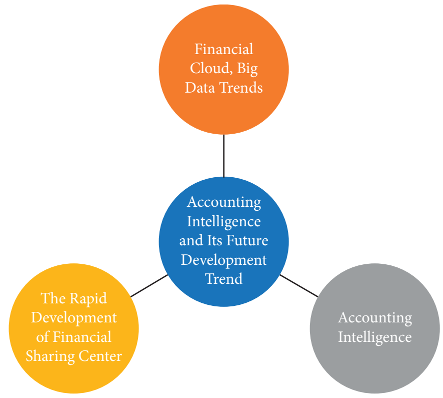

Figure 4: Accounting intelligence and its future development trend.

4. Accounting of the Water Company Based on Combination Algorithm

4.1. Improved Apriori Algorithm. The basic idea of Apriori algorithm is a machine learning intelligent algorithm based on frequency set theory [25], which mines frequent item sets through layer-by-layer search iteration method. Considering that Apriori algorithm will generate a large number of candidate sets in the iterative process, the intersection of some accounting accounts is empty in practice. Therefore, the iterative process of Apriori algorithm will generate a large number of invalid candidate sets. At the same time, Apriori algorithm needs to scan the database frequently to complete pruning and frequency statistics, which will greatly reduce the mining efficiency [26].

In view of the shortcomings of traditional Apriori algorithm, this paper proposes an improved Apriori algorithm based on Boolean mapping matrix, combining with combination rules of accounting account. The improvement ideas are as follows:

(1) Build a Boolean account combination matrix, in which the first column represents the number of transaction set W, the second to penultimate columns represent each item in item set *R*, and the last column is the total number of items in each transaction. Boolean mapping rule is as follows: if an item appears in transaction Ti, the matrix elements in the I-th row of Boolean account combination matrix and the column where the item is located are mapped to "1." Then map the matrix elements in the column where the item does not appear in row I to "0" and carry out vector inner product operation on the constructed Boolean account combination matrix. The improved Apriori algorithm can complete the required calculation and statistical work only by scanning the database once, and the algorithm efficiency is significantly improved.

(2) In view of the problem that the traditional Apriori algorithm will generate a large number of invalid candidate sets in the iterative process, this paper puts forward an improved strategy of building candidate sets based on the combination rule of accounting accounts: first, after the compound accounting entries are decomposed into simple accounting entries, all transactions in the set are of three types, namely, one-to-one, one-to-many, and many-to-one. According to the statistical rules of water consumption, when a one-to-many transaction candidate set is built, no more than two statistical combinations can appear in all candidate sets at the same time. Similarly, when a "many-to-one" transaction candidate set is built, no more than two combinations can appear in all candidate sets at the same time. The second is to investigate the correspondence between accounting accounts and make full use of the situation that the account portfolio is empty set to shield invalid candidate sets. Third, in the iterative process of the algorithm, if there is only one item in a transaction, the transaction should be deleted from the learning sample.

After the improved Apriori algorithm designed in this paper optimizes the construction of combined candidate set through the above three strategies, the invalid candidate set generated by the improved Apriori algorithm will be greatly reduced in the iterative process and the running efficiency of the algorithm has been significantly improved. The flow chart and pseudocode of Apriori improved algorithm is shown in Algorithm 1 based on Boolean mapping matrix.

4.2. AOI Algorithm Improvement. In order to explore the relationship between the original water consumption attributes, attribute values, and the combination of accounting accounts, AOI algorithm is introduced. On the basis of attribute compression of attribute values proposed by Hanetal [27], macrotuples are generated step by step and corresponding rules are output by upgrading the concept level of attributes:

(1) Build an original voucher attribute to extract all tuples related to frequent item sets from the original voucher database, take the original voucher name and attribute combination as column names, and make the attribute values corresponding to the combination as column values. In addition, the

Input:$Am\times n$, Minsup
for ($k=2$, Lk-1≠; k++)//Generating frequent k item sets from frequent k-1 item sets
begin
C_k = apriori_gen (Lk-1);//Call the apriori_gen function to generate Ck by Lk-1
For all transactions $T\in$ Ddo
begin
Ct = subset (Ck, t);//t contains the candidate set
For all candidates C ∈ CT
$m_i = M\ (,i_1)$ M $(,i_2)$//Calculate the vector inner product of the corresponding items in the candidate set, where i is the number of columns of matrix A.
qi = COUNT (m_i)//Statistics the summary of column i items
If qi < Minsup Then Delect, I//calculate to generate $A_{m,n-x}$ row intersection matrix $C_{m\times m\ m}$.
$k=k+1$
Go To Line3
L_k = {c ∈ Ct│c.q_i ≥ Minsup}//Output frequent itemset L
Output:LEND
apriori_gen
selectp.it_1,p.it_2,. . .,p.$it_{k-1}$from L_{k-1p},.L_{k-1q},
Wherep.it_1 = p.it_2,. . .,p.it_{k-2} = p.it_{k-2},p.it_{k-1}<p.it_{k-1};
For all itsets c ∈ Ck do//pruning step
If $c\notin L_{k-1}$or c ∈ Anti_B_R//If it does not belong to Lk-1 or violates the rules of correspondence between accounting direction and account
Then delete c from C_k//Delete c
End

ALGORITHM 1: Improved Apriori Algorithm.

original certificate attributes also include attributes and attribute value combinations newly added by the company for internal management.

(2) Count the number of attribute value types in each column. If the number of attribute value types is equal to 1, it means that the combination of the original voucher is positively correlated with the frequent item sets by 100%; at the same time, if the number of attribute value types is equal to the number of tuples, it means that the original voucher and attribute combination are not related to frequent item sets. Finally, if the attribute value type number is between 1 and tuple number, it means that the combination of the original voucher is related to frequent item sets to some extent, but the degree of their correlation is not high.

(3) Attribute-oriented generalization: for the case where the number of attribute value types is greater than 1, it is necessary to combine the attributes of the original voucher with the essence of economic business to improve the concept of the attributes of the original voucher. For some attributes in the original voucher that cannot be generalized, remove this column from the original voucher learning sample database.

(4) Specify the generalization threshold. Compress the attributes by setting the generalization threshold; that is, the progress and efficiency of attribute learning are controlled. For an attribute in the knowledge base table, if the number of types is greater than the specified generalization threshold, it should be further generalized. If the number of tuples of the generalized relationship is still greater than the generalization threshold specified by the user, the relationship should be generalized continuously until the set conditions are met and the algorithm is terminated. Otherwise, remove the attribute from the sample library.

(5) Rule verification: when the type number of the original voucher attribute combination is less than or equal to the set generalization threshold, extract all economic and business data from the accounting voucher database and verify the accounting rules. When all tuples related to the business in the accounting voucher database are true, the accounting rule can be output to the rule base. Otherwise, it is stored in the rule base to be verified, to provide reference for accountants, and AOI algorithm ends.

4.3. Improved Algorithm Based on Water Flow of the Water Company. 7 learning samples are extracted from the water resources flow database (Table 1), and let Minsup be 2. The learning process of the improved algorithm is as follows:

(1) According to the Boolean mapping principle [28], the data of water flow database is binarized, and the generated Boolean mapping matrix is shown in Table 2.

(2) Because the total count of F is less than Minsup threshold, five 1-item set items, A, B, C, D, and E, are formed after deleting F column from the matrix. T6

Table 1: Learning sample of water resources flow (unit: million cubic meters).

Order number	Item	Stock increase	Stock decrease
1	Water of productive use	60	0
2	Domestic water	15	0
3	Environmental water	0	27
4	Import	7	0
5	Export	0	6.3
6	Purchase	5	0
7	Other departments	0.7	3

Table 2: Boolean mapping matrix based on learning samples.

	Do the right	Not supply	Emission	Uncompensated use	Actual water	Others	Total
	A	B	C	D	E	F	
T_1	0	1	1	0	1	0	3
T_2	0	1	1	1	1	0	4
T_3	0	1	1	0	0	0	2
T_4	1	0	1	0	0	0	2
T_5	1	0	0	0	1	0	2
T_6	0	1	0	0	0	1	2
T_7	0	1	0	1	0	0	2
Total	2	5	4	2	3	1	

is deleted from the matrix because the subtotal of T6 transaction is less than 2.

(3) Adopt Apriori_gen function to connect A, B, C, D, and E and generate candidate set C2. As the learning samples are all "one-to-many" estimates, and both A and B belong to the rights of water entities, the AB combination is an empty set, which is directly shielded during the connection process. At the same time, A and D do not constitute a corresponding relationship, so the combination of A and D is an empty set, which should be directly excluded in the connection. The results of vector inner product in candidate set C2 and its corresponding column vector generated by the algorithm are shown in Table 3.

(4) The result of vector inner product calculation of candidate set C2 shows that only four combinations of BC, BD, BE, and CE meet Minsup threshold, so the algorithm adopts Apriori_gen function again, and according to four frequent 2-item sets, candidate set C3 is generated after connection. Table 4 shows the result of vector inner product calculation.

(5) Only BCE in candidate set C3 meets the Minsup threshold, so BCE is the frequent item set; that is, the combination of entity water quantity with the highest frequency leads to the termination of Apriori improved algorithm learning.

(6) Extract all the original voucher sample data related to BCE from the original voucher database, and AOI algorithm is selected to learn.

(7) After deleting the numerical variables (such as "Unused water-surface water –river" and "Unused water - surface water –reservoir") that have no influence on accounting rules in the original voucher attribute database, count the number of attribute values of original vouchers in each column where "Unused water-surface water" is 5 "Unused water consumption-groundwater" is 1; "Unused water-other water sources" is 2.

(8) Set the attribute learning threshold as 2, and generalize the attribute values with attribute types greater than 2 in the database, upgrading each attribute of "unused water-surface water" to "water resources" and upgrading the attribute of "unused water-groundwater" to "water entity." So the

Table 3: Results of the C2 inner product.

Order	AC	AE	BC	BD	BE	CD	CE	DE
1	0	0	1	0	1	0	1	0
2	0	0	1	1	1	1	1	1
3	0	0	1	0	0	0	0	0
4	1	0	0	0	0	0	0	0
5	0	1	0	0	0	0	0	0
6	0	0	0	1	0	0	0	0
Total	1	1	3	2	2	1	2	1

Table 4: Results of the C3 inner product.

Order	BCD	BCE	BDE
1	0	1	0
2	1	1	1
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
Total	1	2	2

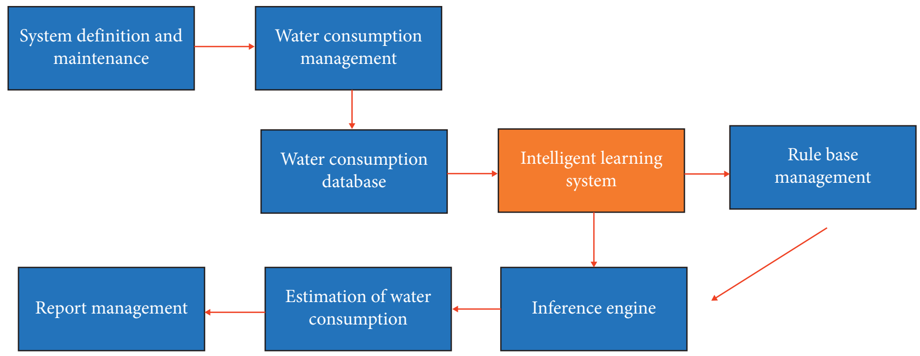

FIGURE 5: Architecture of the accounting information system.

attribute types in all columns are less than or equal to the set threshold.

(9) Extract all economic businesses in the water consumption database to verify the output rules and whether the accounting account combination in the corresponding accounting voucher is frequent item set BCE. If true, the rule is a strong rule that can be stored in the rule base, and the intelligent accounting algorithm is successfully learned. If false, the rule is weak and can be stored in the rule base to be verified.

5. Design of the Accounting System of Water Company Based on the Combination Model

According to the accounting practice process and the demand of intelligent accounting [29], the architecture of accounting information system of water company designed in this paper is shown in Figure 5, and the main functional modules are as follows:

(1) System definition and maintenance: this functional module mainly includes the basic work such as account initialization, accounting period definition, and personnel authority management. At the same time, the system also needs to collect and store a large amount of basic data such as personnel information, organization information, and water rights trading information, which lays the foundation for realizing computer intelligent judgment.

(2) The management of water consumption is an important part of intelligent accounting system which is different from ordinary accounting information system. A large amount of original voucher information needed for the learning and training of intelligent accounting system is collected and stored through this link. With the help of OCR text recognition technology and other intelligent data collection technologies, learning samples can be obtained efficiently and accurately for AOI algorithm [30].

(3) Intelligent learning system is the most important module in the intelligent accounting system, which mainly learns and extracts relevant rules from the database of original vouchers and accounting vouchers. First, preprocess learning sample data, including setting control parameters for intelligent learning of the system and creating Boolean mapping matrix according to the accounting voucher database. Second, mine association rules by calling Apriori's improved algorithm, and output frequent accounting account combination item sets to provide basic data for the original voucher attribute learning. Third, learn the attribute of original water consumption after extracting the learning sample data from the original voucher database. Finally, the inference engine automatically calculates and realizes the important function of automatically compiling accounting vouchers [31].

6. Conclusion

With the in-depth application of artificial intelligence technology in accounting field, accounting intelligence has become one of the hottest topics in the development of accounting industry at present. Focusing on the intellectualization of accounting, by taking computer intelligent judgment as the direction to replace professional judgment of accounting experts, this paper comprehensively applies improved Apriori algorithm and improved AOI algorithm based on Boolean mapping matrix. In addition, data mining is carried out on the relationship between the original water consumption attribute, attribute value, and water right transaction, and a water accounting rule base is formed. On this basis, the computer self-learning under unsupervised mode, intelligent judgment reasoning, and intelligent accounting of self-updating rule base are realized.

Data Availability

All data generated or analyzed during this study are included in this published article (and its supplementary information files).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Aerobic Exercise Fatigue Detection Based on Spatiotemporal Entropy and Label Technology

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Excessive exercise can strengthen the body and make people happy, but it can also cause physical injury. To address this issue, this paper proposes the TFD-SE (Three-Frame Difference Spatiotemporal Entropy) algorithm and the LB (Label Propagation) algorithm, which are both based on SE (spatiotemporal entropy) and label technology. The TFD-SE algorithm calculates the difference image using the three-frame difference method, then calculates the SE of pixels in the difference image, and performs morphological filtering and threshold segmentation, allowing it to detect moving objects effectively. The significance value of unlabeled nodes in the image is calculated using the LB algorithm. In both qualitative and quantitative comparisons, the experimental results show that both algorithms outperform other classical algorithms in terms of detection performance.

1. Introduction

Fatigue is caused by a variety of factors. Fatigue can be classified into four different categories [1–3]: according to the first classification, fatigue is a transitional state between waking and sleeping with no clear distinction between the two; according to the second classification, fatigue is divided into psychological and physiological fatigue; the third type of fatigue is divided into four categories: psychological, pathological, mental, and physical fatigue; and the fourth classification is based on the most common clinical fatigue symptoms. Athletes and soldiers are two examples of occupations that require extensive sports training on a daily basis. Overtraining weakens the training effect while also increasing the risk of more serious side effects such as syncope, muscle injury, and even sudden death [4]. As a result, sports fatigue detection is critical for human safety. There are two parts to sports fatigue detection: sports data acquisition and data-driven recognition algorithm [5].

Aerobic exercise fatigue detection plays an important role in the fields of biological identification, biological monitoring, production, and breeding. In recent years, many methods have been put forward to solve this problem. Among them, the background subtraction method is one of the most commonly used detection methods [6, 7]. It subtracts the background frame from the current video frame and then selects a suitable threshold for binarization of the obtained image, so as to extract the moving target. Entropy is the representation of average information, which was first introduced in informatics. Knowledge about entropy has been widely used in the field of image segmentation [8, 9]. The edge-based method is considered more suitable for semantic video image segmentation. Because people are very sensitive to the edges of moving objects, the effect of extracting the edges of moving objects from the background largely depends on the preset threshold [10]. Because different image sequences contain different image components and their variable characteristics are obviously different, any preset fixed threshold value is not suitable for aerobic exercise fatigue detection. Affected by physical factors such as friction and slippage, the shape and position of the sensor will cause errors in the data acquisition process, which will reduce the accuracy of the recognition algorithm and fail to get satisfactory results.

To detect aerobic exercise fatigue, this paper uses a combination of SE (spatiotemporal entropy) and labeling technology. The moving target can be detected directly by subtracting the current frame image from the background to obtain the difference image and then calculating the SE of the difference image. This method uses entropy to reflect the strength of biological fatigue and, when combined with label technology, reduces the algorithm's calculation time. This algorithm has low computational complexity, strong parameter robustness, and a clear target and is an effective biological aerobic exercise fatigue detection method when compared to the traditional SE method.

2. Related Work

In recent years, research on human fatigue at home and abroad, especially the research on the influence of fatigue on fatigue, has been increasing year by year. In [11] by comparing with the data of healthy people, it is found that the symmetry of the two parameters and the linear relationship between them are quite different. Literature [12] proves that the muscle imbalance in the lateral and middle parts of the lower leg under fatigue is related to the lateral deviation on the floor of the dynamometer. In literature [13], through running on the vertical pressure plate, the impact speed and pressure are obtained. The results showed that the peak acceleration of the tibia and the acceleration of the shoe upper decreased significantly. Literature [14] studied the characteristic changes of HRV (heart rate variability) of the subjects when riding a power bicycle and found that with the deepening of exercise, the peak value of the high-frequency power of HRV gradually increased from 0.25 Hz to 0.6 Hz, which indicated that the main energy of HRV would gradually shift to the right during exercise. Literature [15] used HRV to study different types of fatigue in healthy people and achieved good results. Literature [16] studied the change in the power spectrum of surface EMG (electromyography) signals before and after fatigue under constant static load and found that the power spectrum after fatigue shifted to the left compared with the whole and peak value before fatigue. Literature [17] found that the one-dimensional EMG time series has chaotic characteristics. They calculated the information entropy of various EMG signals in the reconstructed two-dimensional phase space and analyzed the obtained results to determine the law between muscles and movements. In literature [18], using quantitative recursive analysis, it was found that the percentage of a deterministic segment of sEMG (surface electromyography signal) of biceps brachii continuously increased during exercise fatigue, and it was more sensitive than the change of median frequency MF (median frequency) with fatigue.

On the basis of SE, literature [19] proposes an algorithm for detecting human aerobic exercise fatigue. This method establishes a histogram to calculate the SE value of each pixel point and uses that value to determine whether the pixel point belongs to a moving target. An aerobic exercise fatigue detection algorithm based on entropy map and adaptive state label technology was proposed in the literature [20]. Literature [21] proposed a "center-surround" model, which was realized by using the spatial pyramid's local feature contrast of color, brightness, and direction. Despite the fact that the eye movement point prediction model is the origin of significance detection and has made significant progress, each of these methods has a flaw that will affect their performance in practice. To calculate saliency value, the literature [22] uses histogram information from the image luminance channel. For the first time, literature [23] introduced the saliency filter and used a high-dimensional Gaussian filter to fully express the contrast and saliency measurement standard. To detect salient targets, literature [24] fuses various prior information into conditional random fields. The contrast of the center surrounding the histogram, the spectral residual, and the color space distribution are among the prior data. Literature [25] integrates the appearance information alongside the spatial prior information to calculate the significance value of each pixel in the image one by one. These comparison-based methods are simple to use and calculate, but the results are not always ideal when dealing with complex backgrounds.

3. Research Method

3.1. SE-Based Aerobic Exercise Fatigue Detection. Fatigue is a kind of discomfort felt by human beings. It is a kind of feeling after a great deal of physical or mental work. It will reduce people's ability to finish work. When exercise fatigue occurs, the athlete's heart load will increase continuously, becoming more irritable and irritable than usual, muscle soreness and flexibility will decrease, and the necessary thinking ability in competitive sports such as judgment and reaction will also decrease [3]. Therefore, sports fatigue is a comprehensive physical and mental fatigue with mental, psychological, and physical strength.

As the human body's environment will change greatly during exercise, many physiological indexes of the human body will also change greatly. Among these indexes, which can be more related to the changing trend of human body fatigue, and how to select and calculate these indexes to better monitor and analyze human body exercise fatigue is still under in-depth study. In traditional sports fatigue assessments, the subjective (psychological) assessment method is often used to estimate the fatigue degree of the human body quickly, directly, and effectively. However, because sports fatigue is a complicated process, it lacks objectivity only through subjective evaluation, and it is difficult to analyze and evaluate it comprehensively and accurately.

State recognition has garnered a lot of interest as a new recognition technology. When people walk, the term "Li state" refers to the overall movement state of all body parts at any given time. The size of the step, the degree of body shaking, and the habit of exertion are all different aspects of walking posture. The purpose of state recognition is to determine a person's identity based on their distinctive walking posture. Walking is a movement in which both legs alternately push and cushion the ground. The body's acceleration changes over time during a period of walking. There will be turning points in the acceleration signal, such as maximum and minimum when the lower limb is initially grounded, buffered, and pedaled. Entropy is a measure of how much information is contained in a piece of data in information theory. When entropy is at its maximum, the amount of information obtained is at its greatest.

If a random experiment has N possible results or a random message has N possible values, and the probability of their occurrence is, respectively $p_1, p_2, \ldots, p_n$, then the information amount of these events, that is, entropy, is defined as

$$E = -\sum_{i=1}^{n} p_i \cdot \log p_i, \quad (i = 1, 2, \ldots, n). \tag{1}$$

Because entropy is a measure of information size, which indicates the degree of diversity of an event, entropy can be used to characterize the diversity of pixel states and then reflect the degree of motion intensity of pixel points.

An effective method of aerobic exercise fatigue detection must establish the corresponding relationship of moving targets along the time axis. At the same time, because moving targets not only have the temporal correlation of the moving areas but also have the correlation of spatial gray values, the 2D threshold is extended to detect meaningful aerobic exercise fatigue in the time domain.

In this paper, an aerobic exercise fatigue detection algorithm based on TFD-SE (three-frame difference spatial-temporal entropy) is proposed. The algorithm uses the three-frame difference method to get the difference image of video image sequence and uses the SE principle to detect aerobic exercise fatigue in the difference image. In the process of fatigue detection, first, divide the image sequence into 3×3 blocks and calculate the interframe contrast FCON and local variance LCON of the image sequence for each block.

The probability density distribution of each pixel in the video can be obtained by calculating its histogram. According to the distribution probability of a pixel on the time axis, and the distribution probability of the pixel in space is obtained by spatial coordinates, the sampling space shown in Figure 1 is established in this paper.

Interframe contrast indicates the continuity of pixel gray levels in the same position in different frames in time direction, defined as follows:

$$\mathrm{FCON}(m) = \sum_{x=0}^{2}\sum_{y=0}^{2}\left|I(x, y, t_n) - I(x, y, t_p)\right|^2, \tag{2}$$

in which $I(x, y, t_n)$ represents the gray value of the (x, y) position of the current block and $I(x, y, t_p)$ represents the gray value of the current (x, y) block position of the reference image.

The continuity of gray values of adjacent pixels in the same frame is represented by local variance, defined as follows:

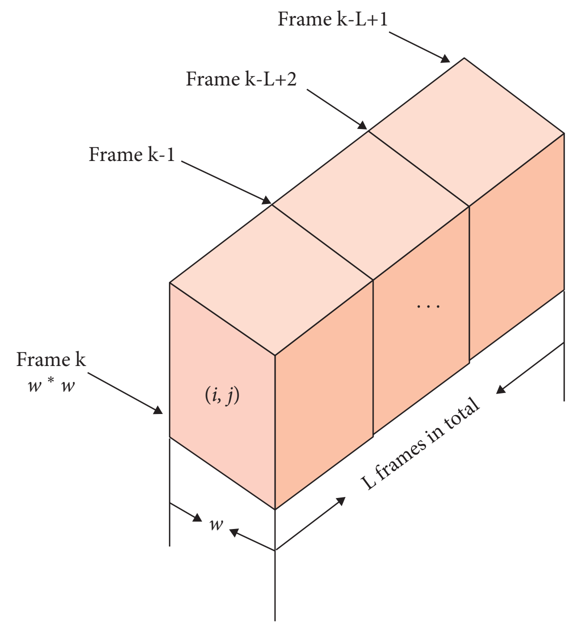

Figure 1: Two-dimensional histogram.

$$\mathrm{LCON}(m) = \sum_{x=0}^{2}\sum_{y=0}^{2}\left|I(x, y, t_n) - \mathrm{MEAN}(m)\right|^2, \tag{3}$$

where $\mathrm{MEAN}(m) = (1/9)\sum_{x=0}^{2}\sum_{y=0}^{2} I(x, y, t_n)$ is the average pixel gray value of the current block.

Calculating the histogram of an image yields the probability density distribution of each pixel. To calculate the histogram distribution of the pixel, a sliding window in time and space is used. The pixel's spatial variation and their variation over time are both represented in the sliding window.

After obtaining the histogram of each pixel, the probability density distribution of pixel (i, j) can be obtained by the following formula:

$$P_{i,j,q} = \frac{H_{i,j,q}}{N}, \tag{4}$$

where N is the sum of pixels in the rectangular window, that is, $N = L \times W \times W$. The probability density of each pixel can be obtained, and the entropy of each pixel can be calculated by (5) to obtain the SE image.

$$E_{i,j} = -\sum_{q=1}^{Q} P_{i,j,p}\log\left(P_{i,j,p}\right). \tag{5}$$

SE reflects the change of each pixel in the image in time and space. If the pixel belongs to the foreground target, $E_{i,j}$ is large, and if the pixel belongs to the background, $E_{i,j}$ is small. Therefore, it can be judged whether the pixel is the foreground target by taking a certain threshold of the entropy image.

The flow of the algorithm is shown in Figure 2.

To begin, edge extraction of video images is performed to obtain three consecutive frames of edge images, after which three frames of difference operations are performed on the

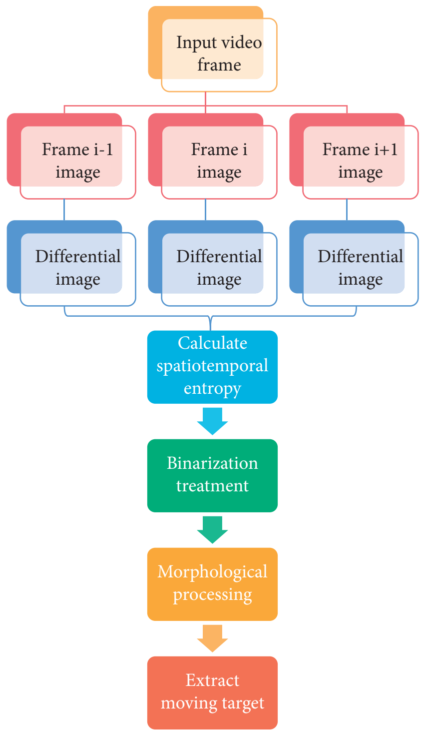

Figure 2: The flow of the algorithm.

three consecutive frames of edge images to obtain a difference image, a two-dimensional histogram of the difference image is established, the SE of the difference image is calculated, and finally, binarization and morphological processing complete the target extraction.

3.2. LB Aerobic Exercise Fatigue Detection. The existing methods of aerobic exercise fatigue detection are basically bottom-up data-driven, and the basic framework is to first define the measurement standards of saliency and then analyze the salient areas or basic pixel units in the image according to these standards, so as to detect the salient targets. These methods mainly use the feature information of salient targets to determine the measurement standard, or some methods detect salient targets according to the feature information of background areas.

In this paper, consider combining these two methods according to the different features information of the salient target and the background area and using the principle of LB (label propagation) to get the corresponding salient maps, respectively, and then fuse the salient maps through an improved Bayesian model to get the final detection result. Figure 3 is the algorithm flow chart of this paper.

The LB algorithm is a semisupervised learning algorithm in a graph model. Its basic idea is to use labeled nodes as label nodes and estimate the unlabeled node information based on the propagation mechanism of the graph model. When the iteration ends, the propagation probability distribution of similar nodes is often similar. The nodes with high similarity are classified into the same class, and then the LB process ends. People generally do not focus their visual attention on the edge of the image. The salient objects in the original image basically do not touch the edge of the image. Therefore, in this paper, the boundary node of the image is used as the seed node of background propagation, that is to say, the boundary node is used as the marked data to LB all other remaining nodes, so as to obtain the similarity measure between the remaining superpixels and the label superpixels, thus obtaining the saliency map based on the background prior information.

In order to meet the measure of significance, this paper needs to normalize the vector to the range of [0, 1]. Therefore, according to the propagation formula, the saliency map using background prior as label node can be calculated, and the saliency value $S_b(i)$ of superpixel node is defined as

$$S_b(i) = 1 - \overline{y}^*(i), \quad i = 1, 2, \ldots, N, \tag{6}$$

where i represents a superpixel node in the image and $\overline{y}^*$ represents a normalized vector. Because the background node is used as the label node in the LB process, the label value of the background area needs to be set to 1.

In most cases, good results can be obtained through the spread of background tags. However, in some images with complex background or low color contrast between foreground and background, the detection results obtained by background prior propagation are not ideal, and a large number of background areas are mistaken for significant targets.

Now, use the foreground target as a label node, so the label vector is known. According to the propagation formula, vector S is normalized to the range of [0, 1], and then the saliency map using the foreground prior information as the label node is obtained. Then the saliency value $S_f(i)$ of the superpixel node is defined as

$$S_f(i) = \overline{y}^*(i), \quad i = 1, 2, \ldots, N. \tag{7}$$

The object-like score is mapped to each pixel using the position relationship and the Gaussian kernel function. Finally, by adding and averaging each superpixel's object-like score, some superpixels with higher object-like scores are chosen as reliable foreground label nodes. This paper converts the saliency map from superpixel level to pixel level before Bayesian fusion for calculation accuracy, which increases computational complexity but yields better detection results.

The formula for calculating the saliency map of pixel level is as follows:

$$S(p) = \sum_{i=1}^{G} \frac{1}{Q_i} \exp\left(-\left(k_1 \left\| c_p - c_i \right\| + k_2 \left\| z_p - z_i \right\|\right)\right) S(r_i). \tag{8}$$

Among them, $S(r_i)$ represents the saliency map of superpixel level, c_p, c_i, z_p, z_i represent the color feature and coordinate vector of pixel p or superpixel area i, respectively, G represents the number of areas directly adjacent to super pixel area r_i, and Q_i represents the normalization parameter. k_1, k_2 are parameters that control color and position sensitivity.

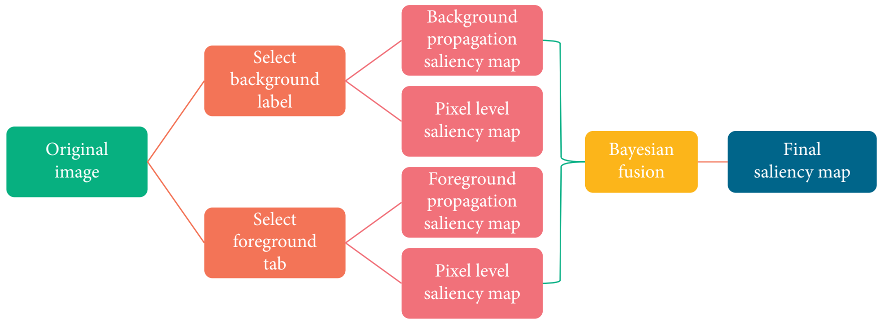

Figure 3: Algorithm flow of LB aerobic exercise fatigue detection.

In this paper, according to the foreground prior and background prior, errors will inevitably occur when selecting tag data, which will lead to inaccurate target detection after passing LB. However, use Bayesian fusion to combine the two propagation results, use the complementary relationship between background information and foreground information, improve the accuracy of the detection target through background LB, and effectively suppress the background area through foreground LB, and finally get the ideal detection effect.

4. Results Analysis and Discussion

Long-term aerobic exercise causes the body temperature to rise and the body heat to rise sharply. To keep the body from overheating, a lot of perspiration and heat dissipation is used to keep the body temperature balanced. The majority of the water lost through perspiration is water which comes primarily from plasma, intercellular fluid, and the intracellular fluid body. Dehydration will occur if water is not replenished in a timely manner, which will have a significant impact on exercise ability. When a person's water loss reaches 2% of their body weight, their working ability drops by 10% to 15%, and when it reaches 5% of their body weight, the athlete's sports ability drops by 10% to 30%.

In this section, the identification model for sports fatigue is constructed by the TFD-SE algorithm and its classification accuracy is tested. First, train the fatigue identification model with ECG (electrocardiogram) and EMG features, respectively, and check the accuracy, and then train and check with EMG feature fusion. Figures 4–6 are statistical results of the classification accuracy of the TFD-SE fatigue identification model constructed by three modes of EMG, ECG, and myocardial electrical feature fusion under a 50% cross-test.

Figure 6 shows that the recognition model trained on ECG and EMG features has a stable comprehensive classification performance and good recognition ability for three types of fatigue states. As a result, the TFD-SE recognition model trained with myocardial electrical feature fusion outperforms the TFD-SE recognition model trained with ECG and EMG features.

Skeletal muscles generate a lot of heat when they are worked hard for a long time. The body will increase heat dissipation to the external environment in order to maintain a constant body temperature. Heat can only be dissipated through perspiration,

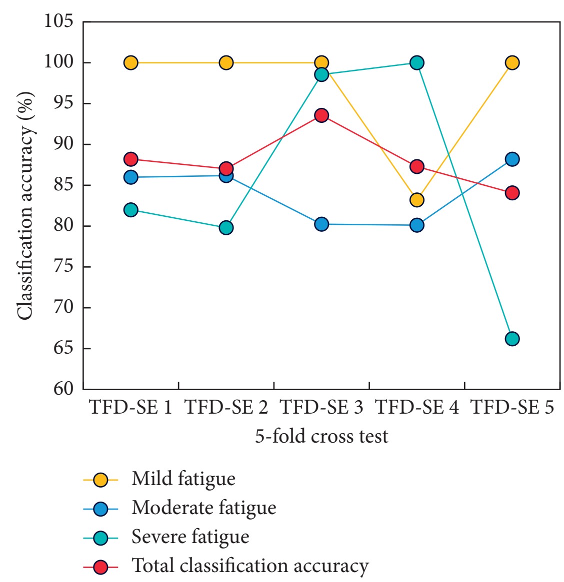

Figure 4: Statistics of classification accuracy of the TFD-SE classification model of EMG feature training under the 5-fold cross-test.

especially during high-temperature seasons when the environment temperature is higher than the body temperature. The body will sweat a lot at this time, and a lot of electrolytes will be lost through sweat, resulting in electrolyte disorder, abnormal neuromuscular excitability, muscle spasms, and decreased exercise capacity. To demonstrate the effectiveness and comparability of the fusion strategy in this section, the unweighted fusion strategy corresponding to the Chinese style in this section is used separately based on tracking with the same features within the framework of the algorithm in this section, and the tracking error is shown in Figure 7.

The time cost of this algorithm mainly focuses on the extraction of each feature and the calculation of similarity, which is directly related to the size of the target and the number of particles. The larger the target, the more particles are obtained and the more time is spent. Therefore, for larger targets, the calculation time can be reduced by sampling the target and reducing the resolution.

Correcting dehydration and providing energy soon after aerobic exercise can help you recover faster. The total amount of liquid and electrolytes lost during exercise should

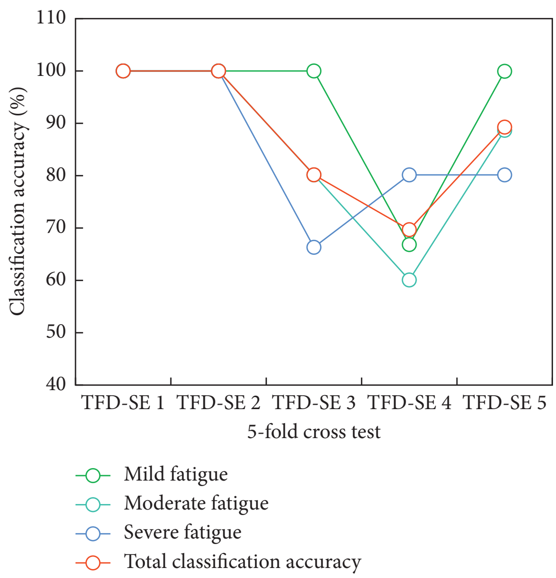

Figure 5: Classification accuracy statistics of the TFD-SE classification model of ECG feature training under 5-fold cross-test.

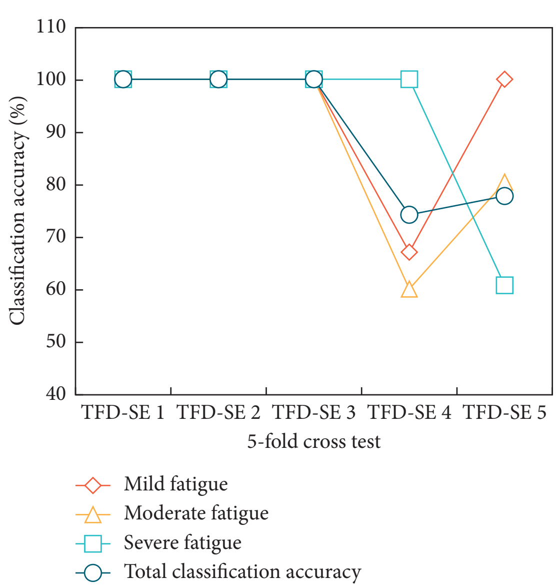

Figure 6: The classification accuracy statistics of the TFD-SE classification model of myocardial electrical feature fusion training under the 5-fold cross-test.

be recovered effectively. To obtain rapid hydration, it is best to consume a sugar-electrolyte beverage after exercise. The sugar content of the beverage can range from 5% to 10%, and the sodium salt content can range from 30 to 40 milligrams equivalent. Vitamin C is an important hydrogen donor in the biological oxidation process, so it is important for aerobic endurance exercise as well. It can speed up the oxidation-reduction reaction in the body, allowing the body to gain more energy and thus improve exercise performance. As a result, taking vitamins after exercise can help to alleviate fatigue symptoms and delay the onset of exercise-induced fatigue.

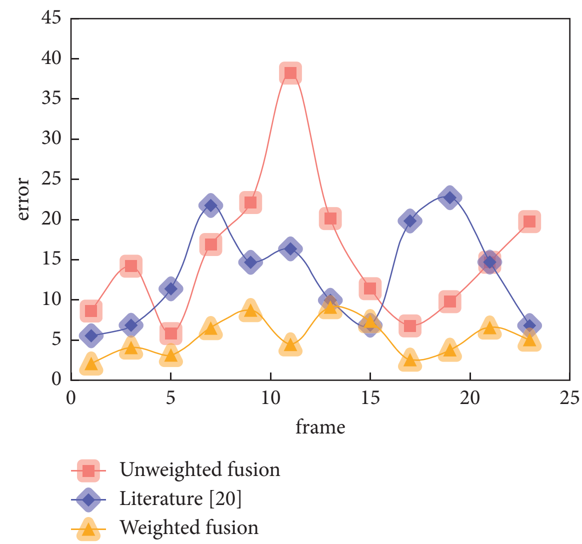

Figure 7: Comparison of error curves of tracking results with different fusion strategies.

In order to make this model more convincing in its aerobic exercise fatigue detection performance, compare it with other existing classic algorithms. In this paper, the F-measure value, recall rate, and AUC (area under the curve) value of these aerobic exercise fatigue detection algorithms will be evaluated on the ASD image database. The results are shown in Figures 8–10.

The accuracy-recall curves of different models are shown in Figure 8. The model in this paper can achieve an accuracy of 0.96 in most range of recall rate and is obviously superior to most detection models. The detection effect of literature [18] is close to that of this model, and the detection performance is slightly higher only in some parts with a low recall rate.

Many isolated small areas and gaps often appear in the binarized image, which will affect the extraction of moving objects. Therefore, the isolated small areas in the binarized image are removed by the image morphology method, and the small gaps are filled at the same time. In morphological processing of binary images, firstly, the isolated small areas are removed by the corrosion operation, and then the small gaps are filled by the expansion operation. On the one hand, it can eliminate noise, and on the other hand, it can smooth the image so that the moving target can be completely detected.

Figure 9 shows the average accuracy rate-recall rate and f-measure value of different models. It can be seen that the average accuracy and F-measure value of this method can reach 9.4 and 8.8, respectively, which is also better than other methods.

It has been established that when the human body participates in high-intensity sports, the strength is primarily maintained by an increase in the central nervous system impulse frequency [16], and the central nervous system constantly sends out high-frequency impulses during the movement. Due to the abrupt change in illumination, color and texture features lose their tracking performance when pedestrians pass through the illumination area. Despite the fact that edge features are less affected by illumination, they lose

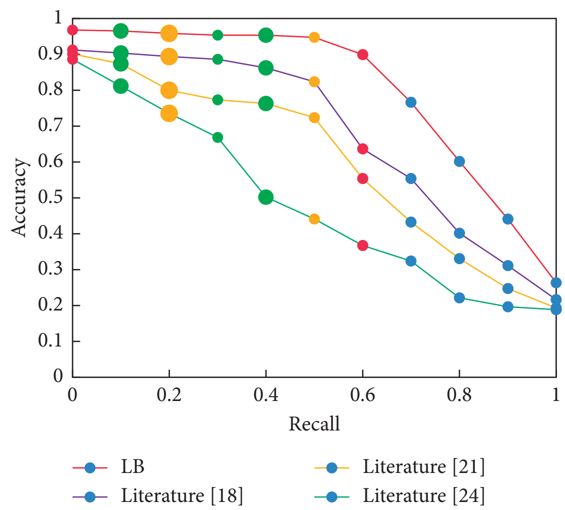

Figure 8: Accuracy-recall curve.

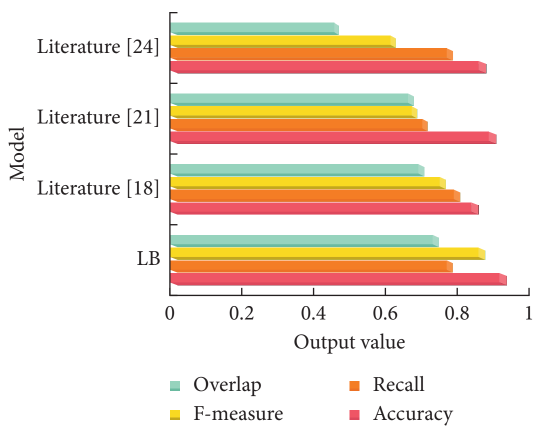

Figure 9: Average accuracy of different models-recall rate and F-measure value.

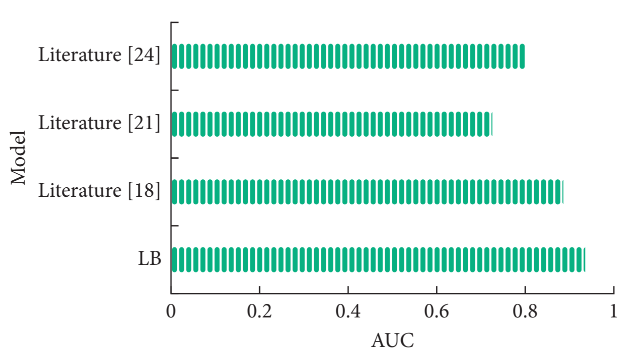

Figure 10: Comparison of AUC values of different models.

their effectiveness due to strong edge interference from object shadows in the illumination area, as the literature [21] shows.

Although the algorithm in this section is affected by the same influence, it also introduces the motion feature, which effectively distinguishes the moving pedestrian from the static background, allowing the tracking algorithm in this section to reliably track the target throughout the sequence.

The texture features are a good supplement when there is background interference. When the head rotates out of the plane, the color and texture features change abruptly, whereas the edge features can effectively capture the head's contour occlusion, which has not changed significantly. Many features are affected to varying degrees when the occlusion occurs due to the various positions and degrees of occlusion, but after fusion, the tracking effect remains stable and effective.

Figure 10 shows the comparison of the AUC values of different models. Aerobic exercise fatigue detection can be simply understood as a second-class classification problem, the purpose of which is to distinguish the prominent target from the background. The AUC value reflects the performance of this classification model. It can be seen from the figure that the AUC value of this model is slightly higher than those of other models and has reached 0.935.

It can be seen from the figure that highlights appear in some background areas. This is because there is no internal connection between the nodes in the background area of the image, which makes the detection algorithm unable to effectively distinguish the background area from the salient objects. After adding thegeodesic constraint, the connection between boundary areas is strengthened, and some obvious targets are not detected by using only one layer of neighbor nodes. This is because the neighbor nodes in the first layer did not make full use of the spatial information in the image, which led to missing some targets in aerobic exercise fatigue detection. However, if all the image nodes were regarded as neighbor's nodes, it would not only increase the amount of calculation, but also reduce the detection effect.

The results obtained by the LB formula have been able to detect remarkable targets well in this paper, using the characteristics of boundary prior and geodesic constraints. The background tag nodes are then hoof selected, and the contact boundary of obvious targets is minimized as much as possible, making the method more robust in this paper. Bayesian fusion takes advantage of the complementary relationship between background and foreground prior information to effectively suppress background noise while uniformly highlighting the prominent targets.

The results of the experiments show that applying the entropy principle in informatics to the field of biological aerobic exercise fatigue detection is feasible and effective, and that it effectively improves and solves the problems of irregular movement and slow detection speed of biological targets in fatigue detection, as well as corroborates the theoretical basis that entropy can reflect the strength of moving targets. This method has a low algorithm complexity, strong parameter robustness, and superior antinoise ability when compared to the traditional aerobic exercise fatigue detection method. It is a reliable biological method for detecting aerobic exercise fatigue that can be applied to biological identification, biological monitoring, and other fields.

5. Conclusion

The detection of aerobic exercise fatigue is investigated in this paper using SE and tag technology, which collects and processes human gait acceleration signals. The TFD-SE is used to propose a new algorithm for detecting aerobic exercise fatigue. The results of the experiments show that using entropy-related principles in informatics to detect aerobic exercise fatigue is feasible and effective. Saliency maps based on foreground information propagation and saliency maps based on background information propagation can both be obtained using the LB algorithm at the same time. The saliency map generated by this model can effectively suppress background noise and highlight saliency targets uniformly and accurately, as evidenced by comparisons of visual effect maps.

The relationship between EEG and exercise fatigue is only explored in a broad sense in this paper. In the future, more research and excavation will be done on this topic.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

Acknowledgments

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Research Article

Application of Decision Tree Algorithm in Early Entrepreneurial Project Screening

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Venture capital firms are always faced with insufficient information and insufficient time when evaluating whether startups are worth investing in. This paper focuses on how to combine the public information of startups with the decision tree algorithm to assist investors in project screening. By extracting the public information of 1104 AI and big data companies from January 2016 to June 2017 and the financing progress in the following 18 months, this paper finds that: the six indicators of having a working background in well-known companies, being reported by well-known media, having patents and being invested by excellent institutions, working experience is highly related to this venture, and having well-known financing consultants can effectively help investors screen out projects that can obtain sustainable financing, that is, high potential projects. Considering the problem of data availability in the real world, combined with industry experience, this paper makes a more detailed variable mining for semistructured information, such as the team resume of start-ups, and selects a decision tree algorithm that is insensitive to missing values and has strong interpretability to amplify the value of fragmented information. Finally, by the improvement of the algorithm, a project screening model that can meet the needs of investment practice is designed, and the fusion mode of public information and private information is discussed, which has a more complete guiding significance for optimizing investment work.

1. Introduction

Venture capital is a form of investment that provides capital for start-ups with high growth potential in exchange for equity. Massive entrepreneurial projects and high investment costs pose a great challenge to fund managers. How to screen as many high-quality entrepreneurial companies in the market as possible under the condition of limited manpower and time, identify their development potential, and provide support is the first kind of problem faced by investors, i.e., time constraints. Another consensus is that there is a serious lack of information in the field of early investment. In the face of newly established companies, investors often cannot obtain hard data about the market, products, and finance, and they can only make decisions under imperfect information in combination with their own experience, industry estimates, and the judgment of the start-up team. In this process, which factors should be given a higher weight, and how to reduce the components of subjective assumptions and make decisions more rational are the second kind of problems faced by investors, i.e., information constraints.

Facing the problem of insufficient time and information, an intuitive solution is to let the machine assist people to collect and process more information, precipitate the decision-making knowledge in the way of algorithm, and rationalize the investment process. However, a series of questions, such as which channels, what information to extract, what indicators to refine, and what feedback to modify the model, need some definition to be effectively answered. Therefore, this paper extracts the link of early project screening from the whole process of investment activities and simplifies the problem as follows:

Assume that an investment institution has obtained the profile of an early-stage company disclosed in the venture capital media, including the endorsement information of relevant parties, such as "past investors," and the information of team characteristics, such as "profile of team members." Can this institution predict the company's potential to obtain the next round of financing based on the financing development of related companies in the same industry over the past period of time? Finally, decide if it is worth the time to research and follow up on the investment.

The two types of input required to answer this question have been extensively studied in academia.

In terms of team characteristics, the positive effects of industry-related experience [1, 2], entrepreneurial experience [1, 3, 4], and well-known company work background [5, 6] on the development of startups have been supported by most literature. However, studies on demographic factors are currently scarce. In the dimension of stakeholders, the endorsement of investment institutions [7, 8] and social capital [9, 10] are positive to the development of the company. The value of financing consultants, venture capital media, and other relevant parties has not been fully explored.

Therefore, this paper attempts to apply the research results of academia on venture capital decision-making and the influencing factors of startups to real investment activities, and based on semistructured public datasets, extract valuable traditional indicators from as many dimensions as possible and novel metrics to test its predictive power.

Therefore, this paper attempts to apply the research results of academia on venture capital decision-making and the influencing factors of startups to real investment activities, and based on semistructured public datasets, extract valuable traditional indicators from as many dimensions as possible and novel indicators to test its predictive effect.

2. Data Preparation

2.1. Data Sources and Extraction Methods. Since the potential of a startup is a latent variable, the effectiveness of the predictive model needs to be validated by explicit indicators. Therefore, this paper selects "whether to obtain the next round of financing," which is highly related to the company's potential, as a proxy variable to test the effect of "team capability signal" and "relevant party endorsement signal" in building a predictive model. Considering that companies that have never raised funding have less publicly available information, we target our research on startups that have raised at least one round of funding [11].

In practice, different industries have different investment analysis frameworks, and the timing and market enthusiasm have a significant impact on the difficulty of obtaining financing for entrepreneurial projects. Therefore, this paper, firstly, controls the industry and time window, and it selects all investment and financing events in the field of artificial intelligence and big data from January 2016 to December 2018, which is a total of 2527. The source of the data is Xinniu Data (https//:www.xiniudata.com), a third-party venture capital service platform, whose institutional account can provide data export function.

The normal financing rhythm for startups is to complete a new round of financing every 12–18 months. Based on this industry experience, this paper splits the dataset and selects all projects that have received early (round A and earlier) financing between January 2016 and June 2017. After the project, a total of 1104 independent companies entered the sample set. Whether these companies receive a new round of funding between July 2017 and December 2018 will be the predictor variable.

2.2. Data Field Description. The dataset collected in this paper contains 17 original fields: company name, industry field, one-sentence introduction, the current round of financing time, current round, the current round of financing amount, the current round of investor, company introduction, contact information, establishment time, region, company advantages, industry label, team members and introduction, activity performance, and business information [12]. After desensitizing the company name to the company ID, there are 4 remaining fields related to this modeling, all of which are semistructured or unstructured information.

By manually labeling the original dataset, we split the above four fields into the following two categories, with a total of 10 binary variables. See Table 1 for specific field extraction and processing.

The structured processing of information and the processing of missing values are explained as follows:

(1) Invested by excellent institutions (GoodInvestor): If the current round of investors includes excellent investment institutions, the variable is 1, otherwise, it is 0. The definition of an excellent institution is that more than 45% of the projects invested in 2015 have the next round of financing (this proportion is an empirical value and can be adjusted in practice). The information comes from the venture capital institution database of Enniu. If the investment institution does not disclose it, the variable is a missing value, marked with "?"

(2) Have well-known financing advisors (GoodFA): The variable is 1 if the company advantage contains "well-known FA"; otherwise, it is 0. The definition of well-known financing consultants by Enniu Data includes well-known financing consultants in the industry, such as Huaxing Capital and Xiaofan Table (this range can be dynamically adjusted in practice). There are no missing values for this item.

(3) Well-known media reports (GoodCoverage): The variable is 1 if the company advantage contains "famous media coverage," and 0 otherwise. The definition of this label by Enniu Data is that platforms, such as Pencil Road and Entrepreneurship, have an exclusive interview with the target company, rather than a simple financing news disclosure. In practice, this range can be dynamically adjusted. There are no missing values for this item.

Table 1: Field extraction and processing.

Field classification	Processed field name	Data Sources
Relevant party endorsement signal	Invested by excellent institutions	Investors in the current round
	Well-known financing advisors (FA)	Company advantage
	Well-known media reports	Company advantage
Team ability signal	Have patents	Company advantage + team members and profiles
	Working background in a well-known company	Team members and profiles
	Core members have a well-known university education background	Team members and profiles
	Core members have entrepreneurial experience	Team members and profiles
	The members have the same school or work experience	Team members and profiles
	The core team has diverse professional skills	Team members and profiles
	Previous work is highly relevant to this venture	Team members and profiles + company profile

(4) Have patents (Patent): The variable is 1 if the company or its members hold patents, otherwise 0. Among them, patents only refer to the company's invention patents, excluding trademarks, and so on. There are no missing values for this item.

(5) Working background in a well-known company (CompanyHalo): If the team members and their profiles mention well-known internet companies (Tencent, Baidu, Alibaba, JD, Xiaomi, Netease, 360, Sina, Google, etc.) or technology enterprises (Microsoft, IBM, Huawei, Lenovo, sap, Oracle, etc.), then the variable is 1, otherwise, it is 0. If the source field is missing, it is marked as "?"

(6) Core members have a well-known university education background (EduHalo): If the team members and the experience of famous universities in the world are mentioned in the profile, the variable is 1, otherwise, it is 0. If the source field is missing, it is marked as "?"

(7) Core members have entrepreneurial experience (StartupExps): If "continuous entrepreneurship" is mentioned in team members and profiles, the variable is 1, otherwise, it is 0. If the source field is missing, it is marked as "?"

(8) The members have the same school or work experience (CoworkExps): In the team members and profiles, it can be inferred that the core members have studied in the same university or the same company. Then, the variable is 1. If there is no obvious intersection in the main experience, it is 0. If the source field is missing or difficult to judge, it is marked as "?"

(9) The core team has diverse professional skills (DiverseExps): In the team members and profiles, the core members' experience covers at least two items in technology, product, management, marketing, and finance. Then, the variable is 1. If the background of core members is similar, then the variable is 0 (for example, CEO and CTO are from R & D background). If the source field is missing or difficult to judge, it is marked as "?"

(10) Previous work is highly relevant to this venture (WorkRelated): If the team members and the work background mentioned in the profile are highly correlated with the industry or business of the start-up company, the variable is 1, and if it is obviously irrelevant, it is 0. If the source field is missing or difficult to judge, it is marked as "?"

3. Research Design and Model Validation

To make a relatively independent judgment and comparison on the predictive value of the two types of signals, this paper, firstly, constructs two basic models using the endorsement signal of relevant parties and the team ability signal, respectively, and compares the Bayesian network and decision tree C4.5 and random forest. Then, the two kinds of signals are fused to build a comprehensive model to test the improvement of key indicators. Finally, considering the significant difference in the cost of "rejecting the true and accepting the false" in investment practice, this paper introduces a cost matrix to improve the recall rate of the model for high potential projects.

3.1. Basic Model 1: Based on Endorsement Signals of Related Parties. We, firstly, select the endorsement signals of three interested parties—invested by excellent institutions, well-known financing consultants, and well-known media reports—as the model input, and take whether we obtain the next round of financing within 18 months after the first disclosure of financing information as the classification label (yes is 1, no is 0). There are 1104 records in the complete dataset, of which 414 have the next round of financing (defined as a positive sample), accounting for 37.5%.

Under 10 10-fold cross-checks, the average performance of the Bayesian network, decision tree C4.5, and random forest algorithms was tested. The experimental environment is the open-source data mining software Weka, and the algorithm uses the default parameters. Considering the problem situation abstracted from investment practice and how to select a small proportion of samples that cover as many real positive samples as possible, we give the overall classification performance as a reference in Table 2 but focus

Table 2: Basic model 1: endorsement signals of related parties.

	Bayesian network	Decision tree C4.5	Random forest
Overall accuracy	64.2%	63.2%	61.6%
Overall recall	65.8%	64.8%	63.7%
The number of positive samples judged	210	281	256
The actual number of positive samples	123	153	135
Positive sample precision	58.7%	54.6%	52.5%
Positive sample recall	29.7%	36.9%	32.5%

Table 3: Basic model 2: team ability signal.

	Bayesian network	Decision tree C4.5	Random forest
Overall accuracy	68.3%	68.0%	68.2%
Overall recall	69.3%	68.9%	69.0%
The number of positive samples judged	286	249	237
The actual number of positive samples	180	160	154
Positive sample precision	63.0%	64.2%	65.0%
Positive sample recall	43.5%	38.6%	37.3%

on comparing the recall rate and accuracy rate of positive samples (i.e., continuous financing projects).

It can be seen from the above table that the Bayesian network is the model with the highest positive sample precision, and the decision tree C4.5 is the model with the highest positive sample recall rate.

Although the decision tree C4.5 model is slightly lower than the Bayesian network in accuracy, it predicts 30 projects that can get the next round of financing more than the latter on average (153 vs. 123), while only 71 additional projects need to be reviewed (281 vs. 210), which has significant value in practice. Because for investors, compared with the original 1,104 projects, the number of projects has been reduced to 281, which has significantly saved working time (corresponding to a 75% compression rate). 24% more project coverage is desirable in exchange for some additional project viewing time, and the recall of high-potential projects is a major consideration at this time.

In summary, decision tree C4.5 is the best performing model for this requirement.

3.2. Basic Model 2: Based on Team Ability Signal. In the basic model 2, we select seven founding team ability signals as the model input, including having patents, working background in well-known companies, core members having an educational background in well-known universities at home and abroad, core members having entrepreneurial experience, members having the same school or work experience, core teams having diversified professional skills, and previous work is highly related to this entrepreneurship. Then, repeat the aforementioned experimental process.

It can be seen from Table 3 that at this time, random forest is the model with the highest classification accuracy of positive samples, while the Bayesian network is the model with the highest recall rate of positive samples. The difference in precision is slightly lower than the difference in recall. In addition, compared with basic model 1, the three types of algorithms have improved in key indicators. Among them, the positive sample recall rate of the Bayesian network improved the most significantly (43.5% vs. 29.7%). The positive sample precision rate of the random forest algorithm improved the most significantly (65.0% vs. 52.5%).

A possible explanation is that, compared with the related party endorsement signal, the dimension of the team capability signal is richer, however, the proportion of missing values is also higher. Under the characteristics of this dataset, the Bayesian network can learn the rules existing in a small number of samples from the combination of indicators, and the pruned decision tree algorithm is more inclined to learn the negative samples with a higher proportion in the dataset. In the discrimination method, although the size of the selected samples is smaller (the compression rate is above 77%), the recall ability of positive samples is weak.

To sum up, in investment practice, if one encounters a situation with rich attributes but many missing values, the Bayesian network may be the better choice among the three.

3.3. Fusion Model. For base models 1 and 2, the sample compression and precision are acceptable in practice, however, the optimal model does not exceed 44% in terms of recall on positive samples. For investment institutions, the cost of omitting star projects is huge. Only when the recall rate of positive samples is high enough, the model has application value.

To this end, we tried to fuse the endorsement signal of related parties with fewer dimensions and the team capability signal with more dimensions as the model input and repeated the above modeling and testing process. The results are summarized in Table 4.

It can be seen from the above table that compared with the basic models 1 and 2, the three types of algorithms have a large proportion of the improvement in the recall rate of positive samples, and the value of the combination of the two types of indicators for improving the prediction effectiveness of the model has been verified. Among them, the Bayesian network has the best performance. The performance of decision tree C4.5 is in the middle, and the performance of random forest is second. Compared with model 2, the recall

Table 4: Fusion model.

	Bayesian network	Decision tree C4.5	Random forest
Overall accuracy	69.7%	67.6%	67.0%
Overall recall	70.5%	68.5%	67.9%
The number of positive samples judged	327	339	332
The actual number of positive samples	207	203	196
Positive sample precision	63.5%	59.7%	59.0%
Positive sample recall	50.1%	48.9%	47.4%

rate of positive samples for decision tree C4.5 is improved by 10 percentage points.

It is of great significance for investment practice. Take decision tree C4.5 as an example. Its practical meaning is as follows: after 1104 projects are screened by the model, 339 will be judged as possible for the next round of financing, of which 203 can indeed get the next round of financing. From the perspective of project coverage, if investors screen projects according to this method, they can cover 48.9% of high potential projects under 30.7% of the workload. From the perspective of time cost, investors can spend 59.7% of their working time on valuable projects, which is significantly improved compared with the positive sample rate of 37.5% when looking at projects at random.

However, it is worth noting that even under the optimal model, half of the high potential projects will not be screened out by the algorithm. By tracing back the characteristics of samples and their classification results, it can be inferred that there are three reasons, which are as follows:

(1) Incomplete information. For example, 72 positive samples lack team members' profiles and lack positive signals in the dimension of endorsement of related parties, which objectively limits the upper limit of the prediction ability of the model.

(2) The positive and negative proportions of the samples are uneven. The proportion of negative samples is 62.5%, which is 1.7 times that of positive samples, which makes the model with the goal of reducing the error rate more inclined to learn the discriminative method of negative samples, while the mining of positive samples is insufficient.

(3) There are unobserved influencing factors. Important factors affecting a company's ability to secure its next round of funding may not be limited to the 10 metrics used in the model.

4. Model Discussion and Extension

4.1. Factor Analysis and Rules Summary. This paper designs and validates a predictive model that can be used for early-stage project screening, but in investment practice, prediction results alone are not enough to support project screening. Investors need to understand the decision-making basis behind the model to confirm each other with their past investment experience, correct possible wrong judgments, or add new screening rules. At the same time, investors also need to know which factors contribute more to the prediction to consciously collect this information when contacting entrepreneurs or improve the information quality of these dimensions through other channels.

Considering the interpretability of the rules, this section selects the pruned decision tree C4.5 model as the analysis object, as shown in Figure 1.

As can be seen from the above figure, there are six indicators in the four layers of the decision tree, which are team capability signals (work background in well-known companies, patents, previous work experience is highly related to this venture) and relevant party endorsement signals (reported by well-known media, invested by excellent institutions and well-known financing consultants), three each. They are the most discriminative for judging whether a project can get the next round of financing [3].

There are also observable differences in the 0–1 distribution of these indicators in the whole sample and the positive sample, as shown in Table 5 for simplicity (the proportion of missing values is hidden). Except for "well-known financing consultants," the proportion of the remaining five indicators with a value of 1 in the positive sample is 12–19 percentage points higher than that in the whole sample.

Combined with the classification results output from Figure 1 and the decision tree model, the following four representative investment logics can be summarized from right to left:

(1) 76% of entrepreneurial teams with a working background in well-known companies can obtain the next round of financing (characteristics: strong team ability signal).

(2) 69% of the teams without working background of well-known companies but with well-known media reports and patents can obtain the next round of financing (characteristics: screened by stakeholders and strong technical ability of the team).

(3) 64% of the teams that have no working background in well-known companies and no well-known media reports but have been invested by excellent institutions and whose previous work is highly related to this entrepreneurship can obtain the next round of financing (characteristics: they have been screened by stakeholders and their team ability matches the entrepreneurship).

(4) 55% of the entrepreneurial teams without working background of well-known companies, well-known media reports, and investment by excellent institutions but endorsed by well-known financing consultants can obtain the next round of

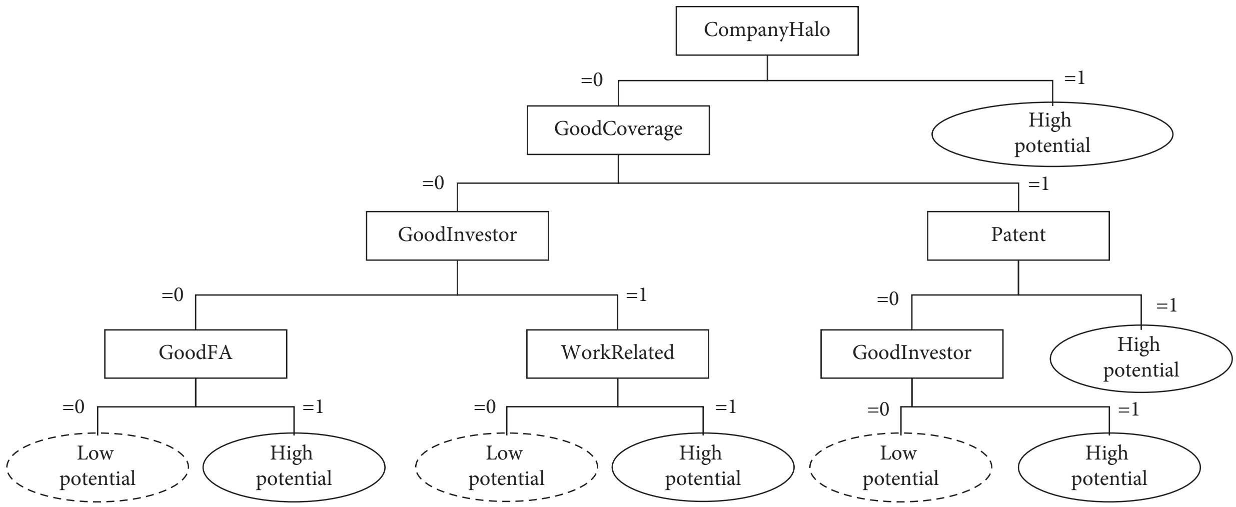

Figure 1: Visualization of decision tree rules (after pruning).

Table 5: 0–1 distribution difference of typical elements in all samples and positive samples.

Variable	All samples		Positive samples only	
	1	0	1	0
CompanyHalo	319 29%	785 71%	195 47%	219 53%
Patent	583 53%	521 47%	272 66%	142 34%
WorkRelated	474 43%	68 6%	257 62%	18 4%
GoodCoverage	272 25%	832 75%	155 37%	259 63%
GoodInvestor	222 20%	726 66%	132 32%	239 58%
GoodFA	134 12%	970 88%	71 17%	343 83%

financing. If the enterprise does not even have the signal of a well-known financing consultant, there is a 70% probability that it will not be able to obtain the next round of financing (feature: when it does not have the signal of team ability, the signal of stakeholders can play a certain screening role).

From the above typical rules, it can be found that the working background of well-known companies is the most differentiated signal. If it does not have this feature, it needs to have at least one of the ability signals of other teams and the endorsement signals of relevant parties to have a higher probability of obtaining the next round of financing.

The language to be converted into investment practice is as follows: if the team has outstanding highlights in its work history, it is worthy of investors' research and follow-up. If the team is average, it needs the investment of other excellent institutions or the information reported by well-known media to be considered.

4.2. Multiclassification Problem. The so-called multiclassification problem refers to using an empirical loss function to predict the classification results of different categories [13]. From start-up to listing, companies usually need to go through more than four rounds of financing (angel round, round A, round B, and pre-IPO round). However, companies that receive continuous financing in the early stage may not be able to go public or be acquired. For investment institutions, if an investment cannot be successfully exited, there will be no return on investment. Therefore, the more valuable the predictive model is to the investment institution, the more the predicted variable can be closer to the long-term potential of the company.

In this regard, an intuitive idea is as follows: after the first financing, companies that can obtain two or more rounds of financing have higher potential and value than companies that have only received one round of financing. In other words, we can classify start-ups into three categories based on the number of follow-up rounds a company has received after their initial funding round, which are as follows: low-value (no follow-on financing, recorded as L), medium value (1 follow-on round, recorded as class M), and high value (2 or more rounds of follow-up financing, recorded as class H).

It should be noted that this multiclassification problem has certain particularities: on the one hand, the three categories are not semantically independent but have a certain degree of progressive relationship. In terms of value, class L < class M < class H. On the other hand, from the perspective of investment practice, both M and H categories should be selected into the project library to be followed up, however, the H category deserves more attention. Therefore, the misclassification between class M and class H does not incur excessive costs.

The original decision tree C4.5 model can handle multiclassification problems but does not pay much attention to the above two problems. Therefore, this section, firstly, uses it as a reference model to measure the general classification effect of the algorithm and then discusses how to improve it.

Table 6: Three classification performance: based on decision tree C4.5 model.

	L	M	H
Sample frequency and proportion	690(62.5%)	294(26.6%)	120(10.9%)
Quantity determined as this category	931	134	39
Actual quantity of this category	627	45	13
Accuracy	67.3%	33.6%	33.3%
Recall	90.9%	15.3%	10.8%

Table 7: Confusion matrix: based on decision tree C4.5 model.

	Classified into L	Classified into M	Classified into H
L	627	52	11
M	234	45	15
H	70	37	13

In terms of datasets, this section follows all the projects that have received early financing from January 2016 to June 2017 in the artificial intelligence and big data industries, which is a total of 1104 projects. The independent variable is consistent with the training set. However, the predictor variable is changed to the number of subsequent financings, with a value of 0 representing no subsequent financing (type L), a value of 1 representing a subsequent round of financing (type M), and a value of 2 represents 2 or more follow-on financing rounds (Class H). Repeating the modeling process and 10-fold cross-checking, the classification performance of the three categories is shown in Tables 6 and 7.

It can be seen from the above table that the decision tree C4.5 algorithm is more biased toward negative samples with a higher proportion (i.e., samples that have not obtained subsequent financing). 84.3% (931/1104) of the samples were classified into the low-value L class, and the identification of medium-value (M-class) and high-value (H-class) samples was severely underidentified. Among the M and H classes, the algorithm also prefers to discriminate as the conservative M class (134 vs. 39). From the perspective of investment practice, this classification effect is not satisfactory.

4.3. Scalability Discussion. It is worth noting that the above models we designed and tested only consider the public information provided by third-party venture capital service institutions, however, in practice, investment institutions can also obtain private information from multiple channels, such as reading project business plans, communicate with founders, communicate with financing consultants, communicate with peers, communicate with colleagues with relevant experience, obtain third-party research data, etc.

The potential value of this private information is fourfold:

(1) Supplements the missing values of each indicator in the original model, and corrects the wrong labels.

(2) Adds new observations to the model to improve the predictive efficiency of the model.

(3) Provides more information about the research subjects (i.e., startups), such as funding amounts and valuations, to design proxy variables that are closer to the company's potential.

(4) Builds a closed loop between forecasts and observations earlier than the market, and iterates models earlier to improve forecasts and gain a competitive advantage.

Therefore, this section focuses on how to combine public information with private information to form a dynamically updated project screening mechanism. Figure 2 presents a conceptual framework considering practical feasibility.

As shown in the figure, after the public information about the project is obtained, it can be analyzed and processed through the following five steps:

(1) Clean and label the data. The dimensions of the labeling can include the ten dimensions proposed in this article, and it can also continue to expand with the enrichment of practical experience.

(2) For projects with relatively complete information, use decision trees or other machine learning algorithms to generate predictions and make corrections based on expert knowledge in investment institutions, thereby generating two sets—projects worthy of follow-up and projects that are not to be followed up for the time being.

(3) Projects that have not been followed up for the time being will enter the waiting pool together with projects with incomplete information before. After investors obtain more information about the team and projects, they will enter the data cleaning process for remarking.

(4) Projects worthy of follow-up and projects not to be followed up enter the observation pool together. Combined with the financing and development information obtained by investors through industry exchanges, projects are divided into four categories: TP (true positive) refers to projects that are determined by institutions to be worthy of follow-up and have real potential through follow-up observation, FP (false positive) refers to the project that the institution determines is worthy of follow-up, however, it is found

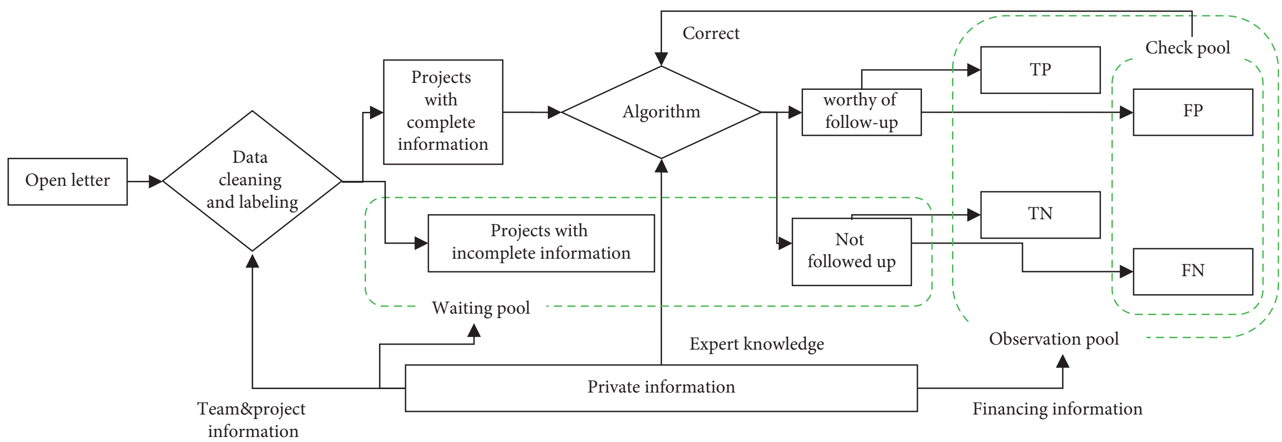

Figure 2: Project screening framework that integrates private information and public information.

that it has no development potential and sustainable financing ability, TN (true negative) refers to the project determined by the organization not to follow up temporarily and found to have no potential in the follow-up, and FN (false negative) refers to the project that the organization determines not to follow up temporarily but actually finds potential.

(5) The misclassified samples (i.e., FP and FN) are included in the check pool, and the dataset is used to modify the previous algorithm.

5. Conclusion

This paper mainly studies the application of the machine learning method represented by a decision tree in early entrepreneurial project screening. The research process is divided into four steps.

The first step is to establish a prediction model that can be used in investment practice. By processing the real investment and financing event data set in the field of artificial intelligence and big data, this paper extracts two kinds of signals, which are as follows: the endorsement of relevant parties and team ability, with a total of 10 indicators. After establishing the basic model based on the two types of indicators and verifying their prediction effectiveness, this paper combines all indicators to test whether the fusion model is significantly improved compared with the basic model. Then, considering that in practice, investors are more interested in projects that can continuously obtain financing (i.e., positive samples). This paper introduces a heuristic misclassification cost matrix to adjust the weight of the two types of samples and verifies how much the improved model can improve the recall rate of positive samples.

The second step is to interpret the law revealed by the model and to explore whether this law is still applicable over time and whether it can be applied to project screening in similar industries. The selected model is the decision tree C4.5 model with more interpretable rules. By interpreting the top-down judgment path of the decision tree, this paper extracts general rules for guiding project selection.

The third step is to extend the decision tree model from the binary classification scenario of positive and negative samples to the multiclassification scenario of project value segmentation to improve the usefulness of the model in investment practice.

Finally, in view of the private information available to investment institutions in reality, this paper discusses how to incorporate private information into an iterative analysis process based on the model constructed from public information to achieve a more accurate prediction of high-potential projects.

The implications of this paper for management are as follows:

(1) The value of the three team ability indicators, including working background in a well-known company, patents, and work experience, which are highly related to this entrepreneurship in predicting the potential of the company, has been supported by data. When communicating with entrepreneurs or conducting project surveys, investors deserve to verify the authenticity and basis of these indicators from more information sources. In addition, based on the working experience and the subsequent development performance of the company, a more accurate division basis can be established for the scope of well-known companies, the quality and quantity of patents, and the correlation between work experience and entrepreneurship to continuously improve the screening and judgment of projects.

(2) The optimal model and cost matrix settings are different for different classification objectives, and the same is true for different data dimensions. In practice, investors should fully consider their own classification needs and the availability of external data and then select the model with the best classification effect. In addition, in the context of not pursuing model interpretability, it is also an optional idea to introduce algorithms such as Bayesian network and random forest or use integrated learning

methods, such as Bagging and Boosting, to improve model prediction.

(3) On the issue of early project screening, the dimension of relevant party endorsement, which is less studied by the academic community, actually has a high signal value. It is also consistent with the basic common sense of the investment industry. These experiences should be incorporated into the construction of project screening mechanisms based on machine learning methods.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Research on Precision Marketing of Real Estate Market Based on Data Mining

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As one of the basic industries in China, the real estate industry contributes much to the national GDP every year and plays an important role in stimulating the economy. After years of development, the real estate industry has accumulated a large number of sales data, includes the data of customer and construction. However, the utilization of them is still in the stage of extensive collection and use, which is not sufficient for the accumulated data. Therefore, a precise marketing management system for real estate enterprises based on data mining technology is developed in this paper. Through big data mining, the target customers can be accurately subdivided and portraited, which realizes the matching and prediction of resources. On this basis, accurate marketing and promotion of multichannel collaboration are implemented, which realizes the innovation of real estate marketing mode in the era of big data.

1. Introduction

With the rapid development of information technology, the use of Internet+, 5G, cloud computing and mobile terminals has brought us into the era of big data [1]. Big data technology has become a hot topic at present that the arrival of big data era promotes the interaction between human beings and makes exchange of information more convenient, which also makes the Internet economy more closely linked, so that people can create wealth without leaving home [2–4]. “Big data” has penetrated into all walks of life, which subverts the operation thinking and marketing mode of many traditional industries. In this context, big data touches the nerves of the real estate industry, and real estate enterprises can accurately understand the demand of consumers, so as to formulate accurate marketing strategy [5].

As an emerging field, data mining has a wide range of application prospects, and has been widely used in all walks of life [6, 7]. The combination of real estate field and data mining technology is a topic that researchers are devoted to studying in recent years. It is meaningful to using data mining technology to research and analyze the application of big data in real estate marketing.

2. Overview of Data Mining Technology

Precision marketing is based on the collation and analysis of customer s’ data, which can accurately grasp the demand of customers, provide customers with appropriate products and marketing means, and realize the company’s interests. Data mining, including clustering analysis, discriminant analysis and factor analysis, is commonly used in practical technology [8].

2.1. Definition of Data Mining. Berry and Linoff [9] defined data mining as the process of exploring and analyzing large amounts of data in order to discover meaningful patterns and rules. A large number of data may be partly noise data or fuzzy data. The object of data mining can be a database, a file system, or any other data collection organized together.

The data set in the real estate database includes real estate sales data and feature data of real estate. By randomly extracting part of the data, and data conversion, analysis and other processing, we can find the key data that needed for the development of real estate sales strategy [10, 11].

Data mining is divided into directed one and non-oriented. The purpose of directed data mining is to interpret or classify a specific target domain. The purpose of non-directional data mining is to find out the pattern or similarity between batch data without preseting target domain or class.

2.2. Steps of Data Mining. The specific steps of data mining often take different steps or processes depending on the industry, technology itself and its situation. In addition, whether the data is complete or not and whether the professionals are skilled will also have an impact on the process. Therefore, the industry generally believes that the degree of systematization and standardization of data mining process, and there is a positive correlation with the value of the information. Usually, the main steps of data mining can be broken down into the following programs [12–14]:

(1) Understand the data and the source of the data
(2) Acquire relevant knowledge and technology
(3) Integrate and check data
(4) Remove erroneous or inconsistent data
(5) Establish models and assumptions
(6) Actual data mining work
(7) Test and verify the mining results
(8) Interpretation and application

The above steps show that there are a lot of related preparatory activities before the real implementation of data mining. While statistics show that data preprocessing takes more than 80% of the data mining work, including data filtering, format conversion, variable integration and data table linking [15–17] is shown in Figure 1.

2.3. Methods of Data Mining. The purpose of data mining is to mine valuable information. In order to realize data mining, we need to adopt certain methods, which is helpful to the better realization of data mining [18]. It can be completed by different methods and means, while users can choose the appropriate method according to their own needs. The following content describes several common methods:

2.3.1. Data Summary. The word "summary" is not difficult to understand literally, which is to use simple and concise sentences to summarize the more complex issues, so that people can understand the content of the exposition in a short time. In the same way, data summary is to concentrate the existing data in certain ways, such as through statistical methods such as sum and average, The calculation results of the data are reflected by charts. In addition, the common chart models are column chart and pie chart [19]. Data mining *i* is actually a process of data summary, but its research is more in-depth, which needs a more comprehensive summary of the data from a deep level and a wide angle. Generally, the data are analyzed, synthesized, abstracted and summarized in order from low level to high level, so as to find out some internal relations of these data, and judge the direction of future data development through these laws. According to the methods, it can be divided into multidimensional data analysis method and attribute oriented induction method.

2.3.2. Classification Mining. Classification mining refers to the classification of data in order to mine its potential value. It mainly classifies the data by mapping, so as to correctly classify the data to be processed. There are many ways to construct classifiers, while statistical method, machine learning method and decision tree method are commonly used [20, 21].

2.3.3. Cluster. Cluster refers to aggregate classification, that is, the data with the same characteristics are classified, aggregated and stored separately. In this way, the relationship between data is very clear, and the data belonging to the same category have the same or similar categories; on the contrary, data in different categories have different categories which is helpful to the later work. Statistical method and machine learning method [22] are commonly used in clustering methods.

3. Design of Precise Marketing Management System Based on Data Mining

3.1. Demand Analysis. The purpose of functional requirements analysis is to clarify the functional indicators of the real estate precise marketing management system, that is, the function points that the system should have. In the development of software, there are many tools used to describe users' requirements. This section will discuss them in detail through use case diagrams.

The overall use case of precision marketing management system is shown in Figure 2. The users of the target system mainly include enterprise leaders, market leaders, salesmen and system administrators. In addition, the business of the system can be roughly divided into real estate management, house management, building management, sales management, customer management, decision support and system management.

The real estate management mainly completes the maintenance of the basic information of the real estate, including the business of adding, deleting, modifying and querying the information of the real estate, and the users mainly include the person in charge of the market and the system administrator.

Building management mainly realizes the maintenance of building basic information, including the business of building information addition, building information deletion, building information modification, building information query and so on. The users involved include market leader and system administrator.

Housing management is the management of room information, which mainly maintains the specific information of the room, including the business of adding housing information, deleting housing information, modifying

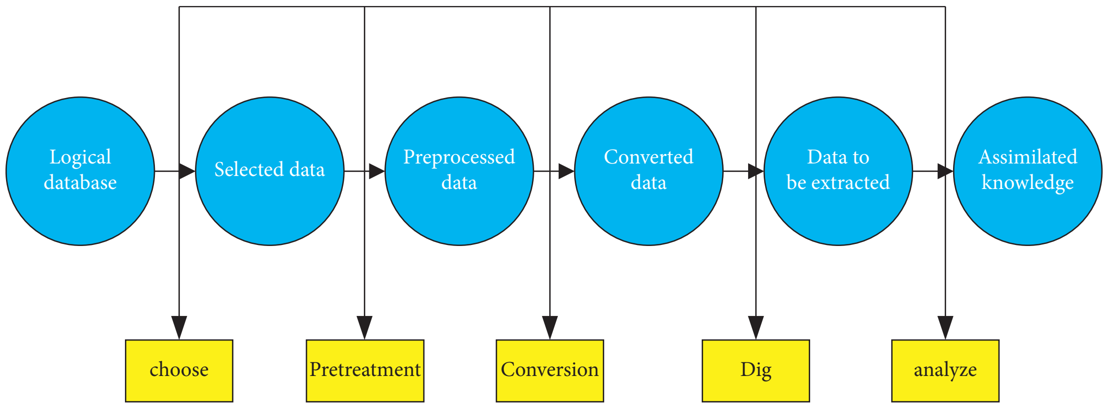

Figure 1: Basic process and main steps of data mining.

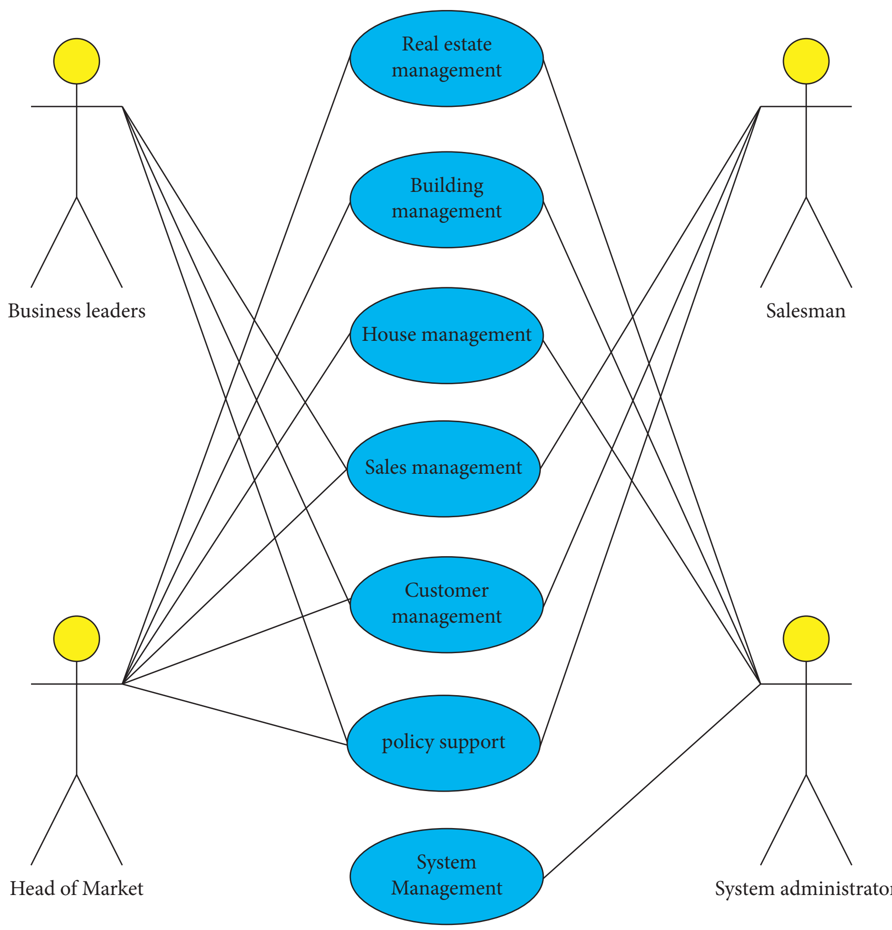

Figure 2: Overall diagram of system.

housing information, querying housing information, etc., and the users involved are market leaders and system administrators.

Sales management mainly maintains the basic information of real estate sales, including sales opportunity management, sales record management, sales performance management, etc., and the users involved are market leaders and salesmen.

Customer management includes customer information addition, customer information deletion, customer information modification, customer information query, etc. the user roles involved include enterprise leader, market leader and salesman. Among them, enterprise leader can only be responsible for customer information query.

Decision support includes sales forecasting, performance statistics, weekly and monthly performance reports. The users involved include enterprise leaders, market leaders and salesmen.

System management is mainly for system administrators, providing the maintenance of basic system information, including user management, data backup, data restore, permission setting, etc.

3.2. Overall Framework of System. In the overall design of the system, first of all, we need to design the overall framework of the system. The target system is mainly used for the daily sales management of real estate enterprises which mainly targets at the enterprise leaders, market leaders, salesmen and system administrators, and provides different services for diverse users. According to the actual *t* needs of the system, B/S mode is selected as the structure, which is a distributed application architecture based on Web. It can meet the needs of different types of users and is suitable for the development of precision marketing management system [23].

In the process of execution, it will give all the interaction between users to the browser side of the system, that is, the interface layer, and the business and data related operations are handed over to the web server to complete, so that the browser and the web server work together to complete the processing of requests. The architecture of precision marketing management system is shown in Figure 3.

3.2.1. Interface Layer. The interface layer is usually called user layer or application layer. The main function of this layer is to complete the interaction with users. On the one hand, it receives the request messages sent by users to the system, on the other hand, it feeds back the request results completed by the server to users for browsing. For users, this layer is the intuitive that their evaluation of the software will be directly reflected in the user's sense of operation on the interface layer. When a user sends out an access request, the interface layer will receive the request, and then send it to the business logic layer and data access layer. At the same time, the processing results will be fed back to the user's browser through HTML and displayed to the user.

3.2.2. Business Logic Layer. The business logic layer is responsible for executing the part that needs business logic judgment and processing in the user request which is located in the middle of the three layers. It is a bridge between the client and the database and it can be said that it is the core layer of the three layers, and its role is very important. When the interface layer receives the user's request, it will send the request of the logical processing part to the layer, which is responsible for executing it. At the same time, it will also send the request of data processing to the data access layer. In the three layers, the business logic layer has its own responsibilities from the top to the bottom. It also acts as a callee's identity, in this layer, involves a lot of business relations. Therefore, the business logic layer is the core part of the whole architecture.

3.2.3. Data Access Layer. Data access layer is also known as application data source layer. The main function of this layer is to complete the operation of database, including data call and data processing. Through the access layer, you can query, modify, delete and update database tables, and it will provide data call and execution related services for the middle layer. Because the operation of the system cannot be separated from the operation, and the database design of any system is relatively complex and takes up more resources, which makes the performance requirements of the database system higher, so the access mode of the database system should be optimized as much as possible, in order to improve the overall efficiency of the system.

3.2.4. Advantages of Three-Tier Architecture. The reason why the architecture design adopts the three-tier architecture mode is as follows:

(i) The three-tier partition makes the system more flexible, and realizes the maintainability and expansibility of the later functions and performance. Because of the independence of the three layers, it is easy to transplant the database

(ii) It accords with the design idea of "high cohesion, low coupling" in software engineering

(iii) The three layers are independent of each other, and the related functions are relatively clear, which facilitates the development of developers, effectively improves the efficiency of system development work, and shortens the cycle

3.3. Deployment and Functional Structure of System. The precision marketing management system based on Net environment is discussed in this paper, B/S mode is adopted for system structure, C# is used for foreground programming, SQL Server 2005 is used for backstage database, and ADO is applied between foreground and background Net connection to achieve interaction. For the system developed by B/S mode, the deployment can be divided into three parts: client, application server, and database server. The request submitted by the client will be sent to the application server for processing, and then through the operation of the database, the response to the user's request is realized. The deployment of the system is shown in Figure 4.

In the work of system design, the first is to design the overall architecture. When the overall architecture is determined, the design will have an overall direction. The next work is to design the function of the system, that is, to design some functions that the target system needs. This is the most concerned problem of users, which means, it can help users complete specific functions. The target system is applied in the real estate sales management. Therefore, in the demand analysis stage, the author talked with the staff related to sales management in depth, and defined the functional requirements of the system, which also laid a good foundation for the design of functional modules. The requirements of modular design are summarized as follows:

(1) In the process of module division, the system should be divided according to the hierarchy, that is, the system should be first divided from the overall perspective, and then the modules after division should be further divided, so that the final module can be realized in a certain way.

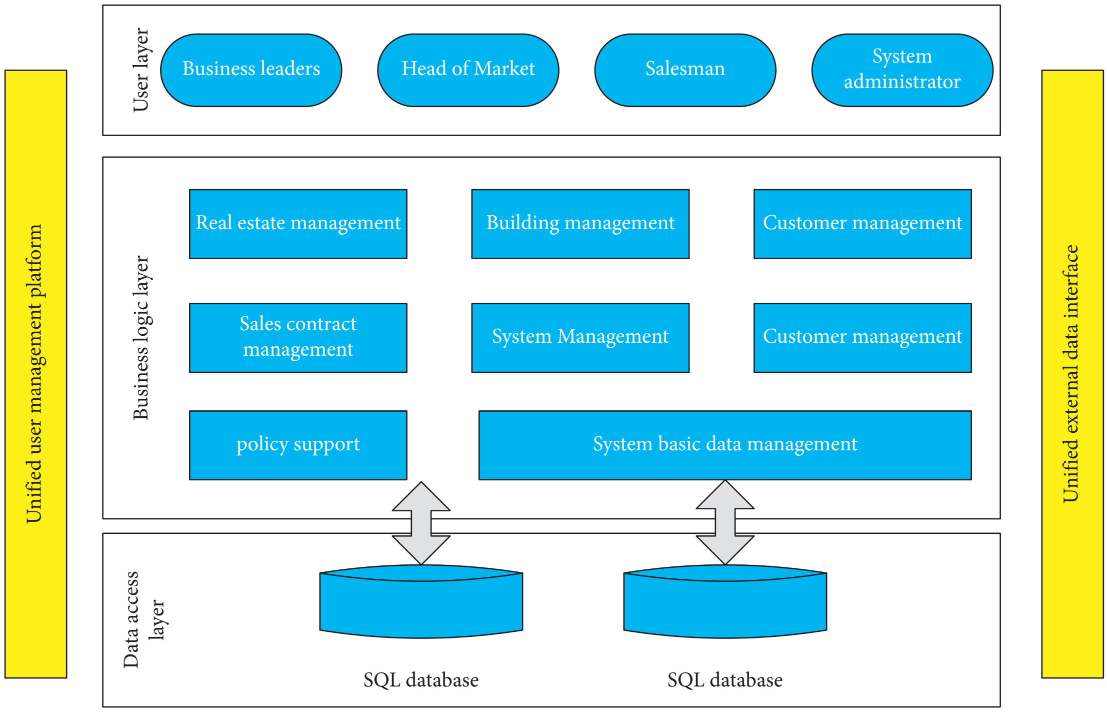

Figure 3: Architecture of system.

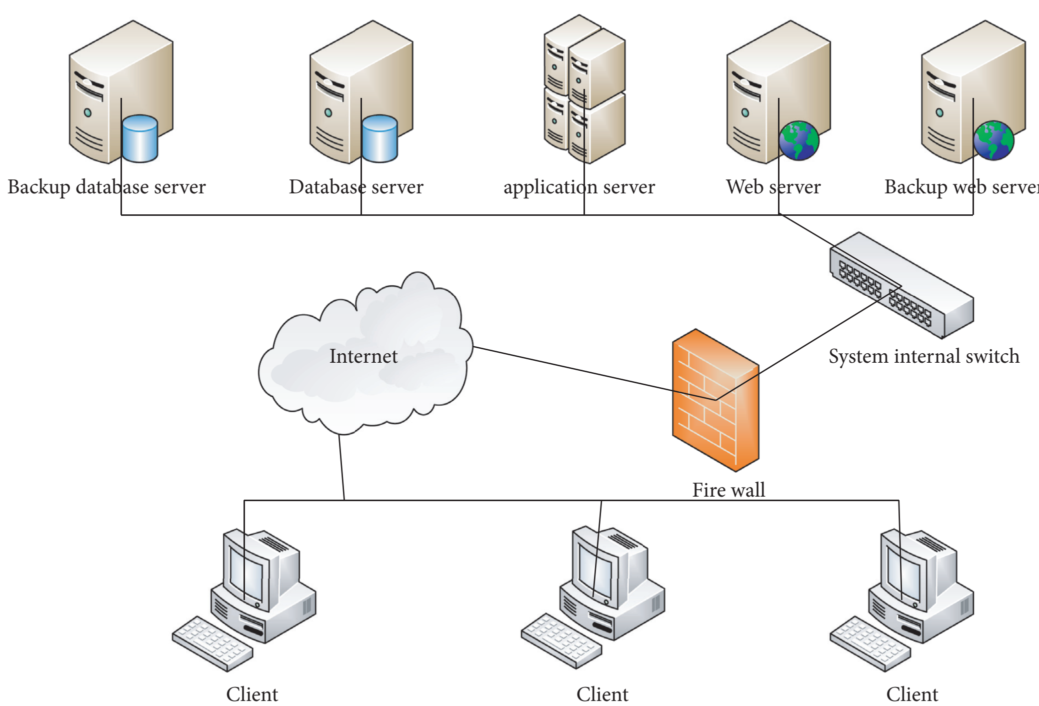

Figure 4: Operation and deployment of precision marketing management system.

(2) All the modules divided should be as independent as possible. In other words, there should be no association between these modules under special circumstances. Of course, this situation is not absolute, but should be avoided as far as possible.

(3) The relationship between the divided modules must be clear. The result of this is to facilitate the later maintenance of the system. When facing problems, the programmer can easily modify it and trace it.

After understanding the requirements of the system function module division, we can divide the function modules of the precise marketing management system. The relevant functional modules mainly include eight functional modules, including real estate management, building management, house management, sales management, customer management, users management, decision support and system management. The function module is shown in Figure 5.

(1) Real estate management: to manage all real estate

  (i) Information addition: add basic information of real estate
  (ii) Information query: query the basic information of the real estate according to the needs
  (iii) Information maintenance: to maintain and manage the basic information of real estate

(2) Building management: to manage the building information in each building of the enterprise

  (i) Information addition: add the building information, including the name, address, area and unit of the building
  (ii) Information query: query the basic information of the building according to the needs
  (iii) Information maintenance: include maintenance and management of related information

(3) Sales contract management: manage the sales contract information of the enterprise

  (i) Add sales contract: enter sales contract information into the system
  (ii) Sales contract maintenance: modify and delete the sales contract information
  (iii) Sales contract query: query sales contract information

(4) Customer management: manage all customers of the enterprise

  (i) Customer data entry: enter new customer information
  (ii) Customer information inquiry: according to the needs of customer information query operation
  (iii) Customer data maintenance: maintain and manage the customer's basic information and data

3.4. Design of Database. According to the process of concept design is the process of data entity design. Based on the previous analysis of the real estate precision marketing management system, part of the data entity design of the system is given below. The main entities of the system include user entity, house entity, building entity, room entity, customer entity, sales contract entity, etc.

The content of database logical design is based on the entities obtained from conceptual design, and transforms each entity into the actual data physical storage structure. This section gives the relevant data tables of the real estate precision marketing management system, and each data table includes the attribute description of each entity. The data tables of the target system include user information table, house type table, room information table, building information table, property information table, property sales information table, customer information table, sales contract table, etc.

The structure of user information table is shown in Table 1. The data table is used to store the basic user information of the system, including the fields of user ID, user name, user type, user real name, gender, age, etc., in which the user ID is the primary key.

The structure of the house type table is shown in Table 2. The data table is used to store the house type information of the room. While this fields included are mainly house type ID, house type name and description, in which the house type ID is the primary key.

The structure of the room is shown in Table 3. The data table is used to store the basic information of the room, mainly including room ID, building ID, floor, room number, house type ID, etc. among them, the room ID is the primary key, and the building ID and unit type ID are foreign keys.

The structure of the building type is shown in Table 4, which is used to store the building type information, including the fields of type ID, type name, type description, etc., in which the type ID is the primary key.

The structure of the building is shown in Table 5. The data table is used to store the basic information of the building. While the fields include building ID, Property ID, unit number, floor area, building type ID, etc. Among them, the building ID is the primary key, and the building ID and building type ID are foreign keys.

The structure of the real estate is shown in Table 6. The data table is used to store the basic information of the real estate. The fields mainly include the property name, developer, floor area, building area, etc., and the real estate ID is the primary key of the data table.

The structure of the real estate sales information table is shown in Table 7. The data table is used to store the sales of real estate. The main fields include sales ID, ID, ID, average price, and number of households sold. Among them, the sales ID is the primary key, and the real estate ID, building ID and room ID are all foreign keys.

The structure of the customer information is shown in Table 8. The data table is used to store the basic information of customers, including the fields of customer ID, customer name, contact number, age, occupation, etc., in which the customer ID is the primary key of the data table.

The structure of the sales contract table is shown in Table 9. The data table is used to store the sales contract information. The fields include sales contract ID, customer name, purchase time, purchase price, payment method, etc. among them, the sales contract ID is the primary key of the data table.

3.5. Design of Interface and Operation

3.5.1. Interface Design. The interface design mainly includes the definition of external interface and internal interface. The detailed design is shown in Table 10.

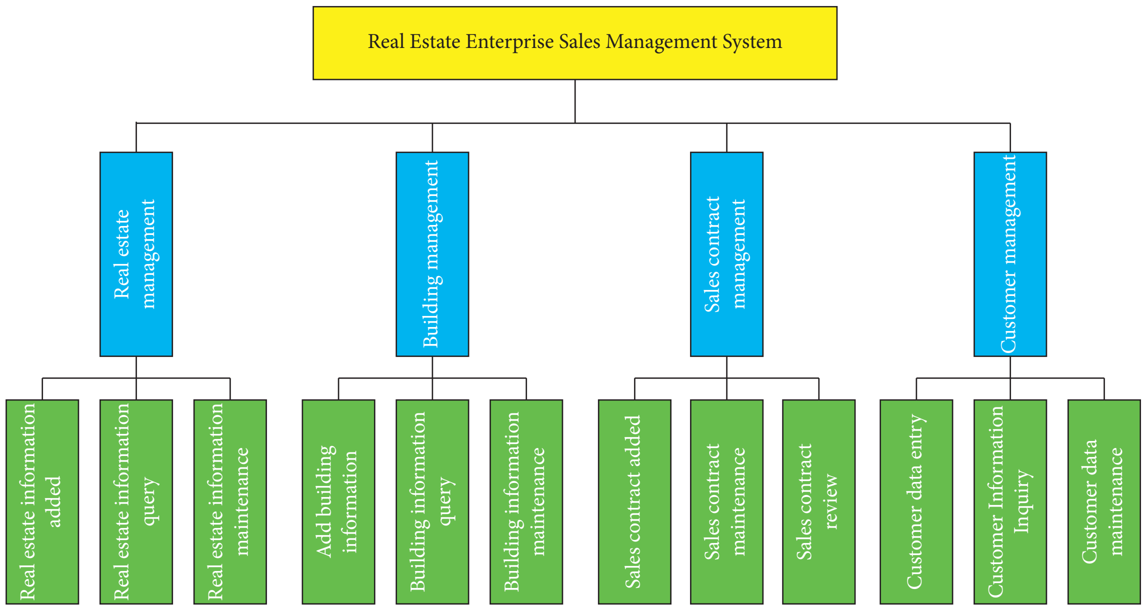

Figure 5: Division of systematic function module.

Table 1: Table of users' information.

Field name	Field type	Data length	Primary key/foreign key	Allow to be empty
User ID	Int	32	Primary key	No
Username	Varchar	20	No	No
User type	Varchar	10	No	No
User's real name	Varchar	50	No	Yes
Gender	Byte	1	No	Yes
Age	Int	11	No	Yes
User password	Varchar	50	No	No
E-mail	Varchar	50	No	Yes
Mobile phone	Varchar	20	No	Yes
User information remarks	Varchar	255	No	Yes
Last login time	Datetime	8	No	No
User's current state	Int	32	No	No

Table 2: House type.

Field name	Field type	Data length	Primary key/foreign key	Allow to be empty
Unit ID	Int	32	Primary key	No
House name	Nvarchar	50	No	No
House description	Nvarchar	50	No	Yes

Table 3: Room information table.

Field name	Field type	Data length	Primary key/foreign key	Allow to be empty
Room ID	Int	32	Primary key	No
Building ID	Int	32	Foreign key	No
Floor	Nvarchar	3	No	No
Room No	Nvarchar	50	No	No
Unit ID	Int	32	Foreign key	No
Use	Nvarchar	50	No	Yes
Area	Int	50	No	No
Construction area	Float	7	No	No
Starting price	Money	7	No	No
Highest price	Money	7	No	No
Average selling price	Money	7	No	No
Sales discount	Nvarchar	4	No	No
Selling price	Money	7	No	No
Balcony area	Float	7	No	No
Room orientation	Nvarchar	50	No	No
Decoration standard	Nvarchar	500	No	Yes

Table 4: Information of building types.

Field name	Field type	Data length	Primary key/foreign key	Allow to be empty
Type ID	Int	32	Primary key	No
Type name	Nvarchar	50	No	No
Type description	Nvarchar	50	No	Yes

Table 5: Information of building.

Field name	Field type	Data length	Primary key/foreign key	Allow to be empty
Building ID	Int	32	Primary key	No
Property ID	Int	32	Foreign key	No
unit number	Nvarchar	10	No	No
Area	Float	7	No	No
Construction area	Float	7	No	No
Building type ID	Int	32	Foreign key	No
Number of layers	Varchar	10	No	No
Number of garages	Int	32	No	No
Number of households per floor	Int	32	No	No
Consumer groups	Nvarchar	30	No	No
Remark	Text	250	No	Yes
Total houses	Int	32	No	Yes
Sold	Int	32	No	Yes
Unsold	Int	32	No	Yes

Table 6: Information of property.

Field name	Field type	Data length	Primary key/foreign key	Allow to be empty
Property ID	Int	32	Primary key	No
Property name	Varchar	30	No	No
Developer	Varchar	50	No	No
Design unit	Varchar	30	No	No
Regional lot	Varchar	20	No	No
Architectural style	Varchar	20	No	No
Area	Float	7	No	No
Construction area	Float	7	No	No
Total number of rooms	Int	35	No	No
Price method	Varchar	10	No	No
Development time	Datetime	8	No	No
Opening time	Datetime	8	No	No
Opening method	Varchar	50	No	No
Traffic condition	Varchar	100	No	Yes
Property management	Varchar	100	No	Yes
Remark	Text	250	No	Yes
File creation date	Datetime	8	No	Yes
Sales call	Varchar	20	No	Yes

Table 7: Information of property sales.

Field name	Field type	Data length	Primary key/foreign key	Allow to be empty
Property sales ID	Int	32	Primary key	No
Property ID	Int	32	Foreign key	No
Building ID	Int	32	Foreign key	No
Room ID	Int	32	Foreign key	No
Average selling price	Float	7	No	No
Number of households sold	Int	32	No	No
Sales rate	Varchar	20	No	Yes
Lowest price	Money	7	No	Yes
Highest price	Money	7	No	Yes
Discount	Float	7	No	Yes
Promotion channels	Nvarchar	50	No	Yes
Total houses	Int	32	No	Yes
Predetermined quantity	Int	32	No	No
Unsold quantity	Int	32	No	No

Table 8: Management table of customer information.

Field name	Field type	Data length	Primary key/foreign key	Allow to be empty
Customer ID	Int	32	Primary key	No
client's name	Varcha	60	No	No
Employer	Varcha	60	No	No
ID number	Varcha	20	No	No
Gender	Varcha	2	No	No
Contact number	Varcha	20	No	No
Address	Varcha	150	No	No
Age	Int	32	No	Yes
Profession	Varcha	50	No	Yes
Demand area	Float	7	No	Yes
Demand floor	Float	7	No	Yes
Demand room type	Varcha	50	No	Yes
Payment method	Varcha	50	No	Yes
Purchase intention	Varcha	100	No	Yes
Number of homes purchased	Int	32	No	Yes
Remark	Varcha	250	No	Yes

Table 9: Contract table of sales.

Field name	Field type	Data length	Primary key/foreign key	Allow to be empty
Sales contract ID	Int	32	Primary key	No
Customer name	Varchar	20	No	No
Purchased room	Varchar	20	No	No
Price	Float	7	No	No
Payment method	Varchar	50	No	No
Salesperson	Varchar	50	No	No
Sales manager	Varchar	50	No	No
Financial officer	Varchar	50	No	No
Payment record	Varchar	250	No	No
Related procedures	Varchar	250	No	No
Delivery time	Datatime	8	No	No
Contract remarks	Text	250	No	Yes
Signing time	Datatime	8	No	No
Signatory	Varchar	20	No	No

3.5.2. Operation Design

(1) Combination of Running Modules. The system mainly takes a window as a module. Generally, a window completes a specific function. While the main window realizes the connection and combination of different functions between modules by opening another sub window. Each module is relatively independent, and the program has good portability. Moreover, the cooperation and data sharing between modules are realized by transferring the reference of data items.

(2) Operation Control. The user opens the system login window and enters the name and password. Then the system jumps to the corresponding background according to the user type corresponding to the name, so as to realize different operations with diverse permissions and roles.

(3) Running Time. The running time of each module should be controlled within 1–2 seconds (most of which is in response to the user's action). As the system adopts message driven mode, it will effectively improve the utilization of computer.

3.6. Algorithm of Decision Tree Construction and ID3 Learning

3.6.1. Decision Tree Construction Algorithm. The construction algorithm of decision tree can be completed by training set T, where $\mathrm{T} = \left\{\langle \mathrm{x}, \mathrm{C_j}\rangle\right\}$, and $\mathrm{x} = (\mathbf{a}_1, \mathbf{a}_2, \ldots, \mathbf{a}_\mathrm{n})$ is a training example, it has n attributes listed in the attribute table $(\mathrm{A}_1, \mathrm{A}_2, \ldots \mathrm{A_n})$ where a_i is the value of attribute A_i. $\mathrm{C_j} \in C = \{C_1, C_2, \ldots, C_\mathrm{m}\}$ is the classification result of X [24–26]. The algorithm is divided into the following steps:

Select the attribute AI from the attribute table as the classification attribute; If there are K_i values in attribute AI, T is divided into k_i subsets $T_1, \ldots, T_K$, where

$T_{\mathrm{ij}} = \{\langle x, C\rangle | \langle x, c\rangle\}| \in T$ and the attribute value a of X is the K_i value;

Delete the attribute AI from the attribute table

For each $T_{\mathrm{ij}}\,(1 \leqslant j \leqslant K_1)$, order $T = T_{\mathrm{ij}}$

If the property sheet is not empty, return (1), otherwise output

At present, the mature decision tree methods are ID3 and C45. Cart, SLIQ, etc.

Table 10: Definition of interface.

External interface	(1) User interface: it adopts windowing and menu design, and responds to hot keys during operation. (2) Hardware interface: printer (3) Software interface: connection to SQL server database through ADO.NET
Internal interface	By defining various classes and methods, the call and data communication with each functional module can be realized;

3.6.2. ID3 Learning Algorithm. Information entropy is called average information quantity in information theory, which is an average value used to measure the information transmitted, which includes a finite number of mutually exclusive and joint complete events. They all appear with a certain probability, which is represented by the mathematical formula [27]: a group of events $X_1, \cdots, X_r$ appears with a given probability $p(X_1), \cdots, p(X_r)$ while the mean value $H(x)$ is the information entropy, and its value is equal to the mathematical expectation of the (self) information quantity $I(x)$ of each event

$$\begin{aligned} H(X) &= -\sum_{r=1}^{r} p(Xi)I(Xi) \\ &= -\sum_{r=1}^{r} p(X_i)\log p(X_i). \end{aligned} \tag{1}$$

In the traditional ID3 algorithm, the information entropy is used as the standard of attributes selection, and the value of information entropy is obtained based on data calculation. Then it is selected by comparing the size of each information entropy, and the item corresponding to the information entropy is taken as the root node of the decision tree. After the example set is divided into subsets by using this attribute, the entropy value of the system is the minimum. It is expected that the average path of the nonleaf node to reach each descendant leaf node is the shortest, and the average depth of the decision tree generated is smaller [28]. In addition, it can be seen that the more fuzzy and disorderly the training case set is in target classification, the higher its entropy is, the clearer the training case set is in target classification, while the more ordered it is, and the lower its entropy is. ID3 algorithm is based on the principle of "the attribute with greater information gain is more beneficial to the classification of training cases". In each step of the algorithm, "the attribute in the table that can best classify the training case set" is selected. Moreover, the information gain of an attribute is the decrease of system entropy due to the use of this attribute to divide the sample, The key operation of ID3 algorithm is to calculate and compare the information of each attribute [29, 30].

The above detailed introduction of ID3 algorithm, in order to better achieve data mining, here will be the basic strategy of ID3 algorithm. The implementation of ID3 algorithm is as follows:

(1) Each node given in the training sample is taken as the root node of the decision tree to start the process of creating the decision tree.

(2) These root nodes are judged and analyzed. If they belong to the same class, they are set as leaf nodes, and the nodes set as leaf nodes are marked.

(3) For the samples that do not belong to the same class, the entropy based measure that called information gain is used as the heuristic information, and the best attribute that can be reclassified is selected from the heuristic information, which becomes the test or decision attribute of the node.

(4) Create a new branch for the new test property and divide new samples accordingly.

(5) The recursive method is used to create a decision tree for each sample. At this time, the attributes of its descendants can not be considered too much.

(6) The recursive process should be repeated until the following features appear:

(i) All the attributes represented by a node belong to the same category.

(ii) The attribute represented by the node does not have the feature of continuous partition.

(iii) If there are no samples under the branches of a tree, the classes in these training sets can be compared and analyzed, and the sample of the largest class's genus is set as the leaf node of the decision tree.

4. System Implementation and Testing

4.1. Implementation of Data Mining

4.1.1. Decision Tree Generation and ID3 Algorithm. The ID3 algorithm proposed by J. R. Quinlan is an earlier and most famous decision tree induction algorithm. Given a set of nonclass attributes C_1, C_2, ..., C_n, Category attribute C and record training set S, a decision tree can be constructed by ID3 algorithm. The ID3 algorithm of decision tree induction algorithm is described as follows [31].

//Returns a decision tree

Function ID3 (R: a nonclass attribute set, C: a Category attribute, s: a training set)

Begin

If s is null, a single node with the value of failure is returned; If s is composed of records whose values are the same category attribute values, and returns a single node with this value; If R is null, a single node is returned, whose value is the most frequent Category attribute value found in s record; The attribute with the maximum gain (D, s) value between attributes in R is assigned to d; Assign the value of attribute d to $\{d_j|J=1, 2, 3, \ldots, m\}$; The subsets of s composed of records corresponding to d_j corresponding to D are assigned to $\{s_j|1, 2, 3, \ldots, m\}$; Then return a tree whose root is marked D and its branch is marked $d1$, $d2$, $d3$, ..., d_m;

Then the following trees are constructed

ID3(R-{D}, C, S_1), ID3(R-{D}, C, S_2), . . ., ID3(R-{D}, C, S_m);

End ID3;

4.1.2. Application of Data Mining in Marketing Management. Combined with the previous analysis, this section analyzes the implementation of data mining with specific cases. Suppose that the following customer information exists in the database, as shown in Table 11.

(1) Step 1: transformation of data. According to the basic data of customer, the required data is transformed by generalization to higher-level concepts which are given as follows:

Data by age are shown in Table 12.

Statistics by income are shown in Table 13.

According to the statistics of purchase area, the statistics are shown in Table 14.

Statistics by marital status are shown in Table 15.

(2) The second step. Get the expected information and information gain. The key to construct a good decision tree is how to choose good logical judgment or attribute. It has been found that the smaller the tree is, the stronger the prediction ability is. To construct a decision tree as small as possible, the key is to choose the appropriate logical judgment or attribute. Information gain here is used to select attributes. The calculation formula of the degree is as follows

Among them, the data set is s, M is the classification number of S, CI is a certain classification label, PI is the probability that any sample belongs to CI, and S_i is the number of samples on classification CI.

(1) Entropy divided by a into subsets: A is an attribute with V different values;

(2) Information gain: Gain $(a) = I\ (s_1, s_2, \ldots, S_m) - E\ (A)$

The split attribute is obtained as follows:

For purchase area:

Info (purchase area) = 0.999215879

Age:

Expected information: info (age) = 0.965202313

Information gain: gain = 0.034013566

Gender:

Expected information: info (gender) = 0.999202348

Information gain: gain = 0.000013531

Occupation:

Expected information: Info = 0.717207246

Information gain: gain = 0.282008633

Marriage or not:

Expected information: Info = 0.958900714

Information gain: gain = 0.040315165

Revenue:

Table 11: Basic data of customer.

Numbering	Age	Gender	Profession	Marital status	Income	Area
1	35	Female	Doctor	Yes	8000	113.7
2	29	Female	Staff	No	4500	95.5
3	40	Male	Manager	Yes	7500	150.5
4	27	Male	Teacher	No	5000	110.5
5	30	Male	Civil servants	Yes	5500	99.8
. . .	. . .	. . .	. . .	. . .	. . .	. . .
130	33	Female	Lawyer	Yes	8000	125.4

Table 12: Statistics of age.

Generation	Statistical data
Under 30	23
31–45 years old	60
46 years and older	8

Table 13: Statistics income.

Income range	Statistical data
Below 3000 yuan	20
3000 yuan-6000 yuan	59
6000 yuan or more	12

Table 14: Statistics of purchase area.

Purchase area	Statistical data
120.00 m2	47
120.00 m2 above	44

Table 15: Statistics of marital status.

Marital status	Statistical data
Married	77
Unmarried	12

Statistics by gender are shown in Table 16.

Table 16: Statistics of gender.

Gender	Statistical data
Male	66
Female	25

Statistics by occupation are shown in Table 17.

Expected information: Info = 0.710086325

Information gain: gain = 0.289129554

It can be seen that income has information gain in attributes, so it is selected as splitting attribute. Node n is marked with age and grows a branch for each attribute value. Then Yuanzu divided them according to this.

Step 3: generate decision tree and extract rules

According to the above data, a decision tree can be generated. The classification rules are extracted from the decision tree.

$R1$: if income = middle and occupation = professor then, purchase area = big;

Table 17: Statistics of profession.

Profession	Statistical data
Nurse	2
Manager	15
Professor	4
Teacher	17
Doctor	13
Entrepreneur	9
Lawyer	8
Staff	23

*R*2: if income = low and marriage = yes, then the purchase area = small;

*R*3: if income = high then house purchase area = big;

*R*4: if income = middle and occupation = doctor and age = senior then, purchase area = big;

*R*5: if income = middle and occupation = business owner then purchase area = big;

5. Conclusion

With the application of mobile Internet technology, 5G, cloud computing and other network technologies, enterprises have an increasing need for big data, especially in the real estate industry. The era of big data brings real estate marketing not only a challenge, but also an opportunity. Real estate enterprises must seize the business opportunity of big data, adjust their marketing mode in time, and promote the successful transformation and upgrading of real estate enterprises. Based on this background, this paper uses data mining technology to design a precise marketing management system for real estate. Its biggest advantage is to realize sales forecast through mining and analyzing customer data, which provides reference for sales personnel to formulate marketing strategies.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Relationship between Parents' Educational Expectations and Children's Growth Based on NVivo 12.0 Qualitative Software

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The relationship between parents' educational expectations and children's growth is a hot topic in family education. In this study, in-depth interviews are conducted with 30 elementary school students and their parents, and the interview data are analyzed by NVivo 12.0 qualitative software. Based on the data from NVivo 12.0, this study initially constructs a model of the relationship between parents' educational expectations and children's growth. This study consists of six parts, including introduction, literature review, research method and materials, results and discussion, and conclusions. The study finds that the educational expectations of elementary school students' parents include three main contents: their children's quality expectations, learning expectations, and life expectations; the differences in perceptions of educational expectations lead to differences in parents' behaviors, which in turn affects the children's growth; parents should maintain high expectations for their children when there is a deviation between children's growth and parents' expectations, and parents should not make a simple attribution to children and lower expectations; parental educational ways and teaching by words and deeds are the guarantees of parents' educational expectations and the conditions for promoting children's growth; national education policy is the fundamental guarantee to promote parents' educational expectations and children's growth. The research conclusions have different opinions on the content and cognition of parents' educational expectations and can provide a scientific basis for parents' family education guidance.

1. Introduction

The parental educational expectation is essentially the goal of family education and training [1]. Under the influence of the traditional cultural psychology of success and excellence, Chinese parents have always maintained high educational expectations for their children's academic performance. The relationship between parents' educational expectations and children's growth has always been a topic of concern in the academic world. At present, China attaches great importance to family education and has promulgated the "Family Education Promotion Law," which means that family education has risen from family affairs to state affairs. Family educators will have a critical role to play in the future in promoting children's healthy development from the perspective of family education. China has also implemented a "double reduction policy" to reduce the amount of homework and extracurricular training required of students. The policy has a big impact on family education and encourages educators and parents to think about what they are doing. Coupled with the fact that the number of parents with a higher education has increased significantly in the new era compared with the past, they often have their own ideas about how to raise their children. As a result of these influences, parents' educational expectations are bound to differ. A thorough examination of parents' educational expectations and their children's development is extremely useful.

2. Literature Review

Past scholars have studied the reasons, content, and effects of parents' educational expectations. Some researchers believe that high parental expectations for children's education come from examination-oriented education, employment pressure, interpersonal comparison psychology (Xining Wu), and parents' educational expectations. Chinese parents' high expectations come from traditional cultural psychology (Xiaowei Yang). Under the impact of the cultural psychology and reality of this kind of educational expectation, parents often give their children too high educational expectations and therefore put forward high learning requirements. When it comes to the content of parents' educational expectations, existing studies have focused on parents' expectations for their children's education and career (Dongmin Zhou). In recent years, scholars have paid attention to the educational expectations of the working class and disadvantaged groups. The educational expectations of the working class parents have highlighted the thinking path of studying hard, entering into a good university, finding a good job, and living a good life, reflecting the orientation of instrumental rationality and pragmatism (Heni Xiong). When talking about the role of parents' educational expectations, most researchers mentioned the Pygmalion effect; that is, the higher the expectations for the child, the better the child's performance (Gong Jing). Parents who convey positive "expectations" to their children will make them advance faster and develop better to stand out in the group (Yali Jiang). In addition, some researchers believe that parents' high educational expectations will cause them to spend a lot of time and energy on their children's academic work, resulting in a preference for intelligence over morality, which will also give children too much interference and deprive them of the space for self-exploration (Huilian Lin). Some scholars have pointed out that this kind of learning pressure imposed on children due to high educational expectations will harm the children. For example, Chen and Xiao believe that parents having too high expectations for their children in terms of learning will affect their children's physical and mental health [2].

Judging from the existing research, the research on the content of parents' educational expectations has more to stop in the "learning expectations." There is insufficient research on children's moral educational expectations, mental health expectations, and interpersonal communication expectations, especially expectation of moral education, because morality is the root of human beings, and the cultivation of children's moral education should be laid by family education [3]. The second is the intermediary variable of the relationship between parents' educational expectations and children's growth, that is, how parents' educational expectations can transform and promote children's growth. It is often limited to the variable research between parents' educational expectations and academic achievement. In addition, the research on the relationship between parents' educational expectations and children's growth is mostly speculative research rather than empirical research in terms of research methods. Although the impact of parents' educational expectations on children's growth has received attention, a review of the existing literature suggests that many questions remain poorly answered. The most representative questions are what the content of parents' educational expectations is, what impact these expectations have on children's growth, what the process of impact is, whether the results of the impact are different from the original educational expectations, what the new changes in parents' "educational expectations" are, and what the effects of these changes on their children are with the increasing importance parents attach to education and the promulgation and implementation of the national double reduction policy. Therefore, this study uses grounded theory methods to study the core content of parents' educational expectations and deeply analyzes the relationship between parents' educational expectations and children's development. It expands the field of research on parents' educational expectations, provides strategic guidance to enable parents to develop reasonable expectations for their children in family education, promotes a good parent-child relationship, and helps children grow up healthily.

3. Research Method and Materials

3.1. Research Method. This research adopts grounded theory to explore the theoretical model of the relationship between parents' educational expectations and children's growth to provide valuable theoretical guidance for parenting. In this study, all the data obtained from the interview are imported into the software for data processing. Grounded theory is not only a methodology, a way of thinking and studying social phenomena but also a research method, which is a procedure and technique for collecting and analyzing data. It requires researchers to maintain the mentality of generative theory at all times, adopt theoretical sampling standards, select research objects according to the needs of generative theory, systematically collect and analyze data, and discover, develop, and test theories from the data [4]. In other words, the grounded theory emphasizes generating theory from research data. This article uses open coding, axial coding, and selective coding on the research data obtained from the interview.

3.2. Research Data Collection. This study discusses the relationship between parents' educational expectations of elementary school students and children's growth, so the interviewees are elementary school students and their parents. The selection of interviewees is mainly based on the following considerations: (1) the grade and gender of the child. Face-to-face interviews are required for basic research, and upper elementary school students can express their ideas more clearly. To ensure maximum access to information, children in the fifth and sixth grades of elementary school are selected. Gender differences in the interviewees may result in the research questions presenting different content, so both boys and girls were selected as the interview sample. (2) The types of children's schools: the characteristics of children and parents varied from school to school. Therefore, the interview subjects are selected from three types of schools. One is suburban schools (some are essentially rural schools), the second is general schools in the city, and the third is high-quality schools in the city. (3) The gender of the parents: fathers and mothers also differ greatly in the education of their children. When interviewees were contacted, it was found that most of those interviewed were mothers, so the author purposely selected fathers for interviews. The details of the interviewees are as shown in Tables 1 and 2.

This interview focuses on research questions and conducts in-depth interviews with interviewees through a semi-structured interview. The interview outline is divided into two versions for parents and children. The parent interview covers the following topics: "What kind of person do you want your child to be?" "What are the aspects you pay attention to in the process of raising your child?" "Do you think you have high educational expectations for your child?" "What are the advantages and disadvantages of high expectations?" The interview with the child involves the following topics: "When do your parents usually praise you and what do they expect and demand from you?" "What your parents expect of you will put pressure on you?"

After finishing the interview recording, a manuscript of about 200,000 words was formed.

To ensure the reliability and validity of the research, this study adopted the principle of typicality and representativeness, interviewing children of different genders, school types, and grades, as well as parents of different genders, educational backgrounds, and occupations. An outline of the interview was laid out around the research questions, and two parents were selected for pre-interview. After the interview, the outline of the interview was adjusted appropriately. During the interview, the interviewer followed up with the interviewee in a timely manner if some of the issues were unclear. In addition, after the emergence of the core categories in this study, an independent new sample was used to test the theoretical saturation.

Table 1: Information of interviewees (students).

	Basic situation	Number	Percentage
Gender	Boy	10	33
	Girl	20	67
Grade	Five	14	47
	Six	16	53
Type of school	Urban high-quality school	10	33
	Suburban school	8	27
	Urban general school	12	40

Table 2: Information of interviewees (parents).

	Basic situation	Number	Percentage
Gender	Male	10	33
	Female	20	67
Age	<38	18	60
	>38	12	40
Education level	High school	1	3
	College	6	20
	Undergraduate	18	60
	Master	5	17
Profession	Full-time mother	5	17
	Teacher	4	13
	Enterprise	5	17
	Company	8	27
	Doctor	4	13
	Freelancers	4	13

3.3. Materials: Data Analysis and Model Construction

3.3.1. Open Coding. The first step of grounded theory is to carry out open coding (open coding), also known as first-level coding, which involves the researcher with an open mind, trying to suspend personal "bias," and carrying out all the information according to its state. The purpose of coding is to discover conceptual categories from data, name the categories, determine the dimensions and attributes of the categories, and then name and generalize the researched phenomena. NVivo 12.0 is used to analyze the interview data word by word; the parents' interview data formed 34 initial concepts and 19 categories. The children's interview data formed 21 initial concepts and nine categories, as shown in Tables 3 and 4.

3.3.2. Axial Coding. The main task of axial coding is to further discover and establish various connections between conceptual categories based on open coding. The parent interview data analysis yielded four main categories and seven subcategories and that of the child interview data yielded three main categories and four subcategories, as shown in Tables 5 and 6.

3.3.3. Selective Coding. Selective coding allows for further systematic treatment of inter-category associations, describes parents' educational expectations in a "storyline" format, and constructs models to represent the relationship between parents' educational expectations and child development during elementary school.

According to the categories derived from the coding, it is concluded in this study that the educational expectations of the elementary students' parents cover three main areas: quality expectations, learning expectations, and life expectations. Parents' educational expectations are closely related to children's growth. The cognition of "expectation" itself is particularly important. Children will regard their parents' educational expectations as an encouragement and a breakthrough in their abilities. However, whether parents adopt appropriate educational practices and teach by words determines whether children can grow up as their parents expect. At the same time, parents' educational expectations depend on the protection of national policies to truly promote children's growth, as shown in Figure 1.

3.3.4. Theoretical Saturation Test. About the theoretical saturation test, the original data from six in-depth interviews (three each for parents and children) are kept for the theoretical saturation test in this study. According to the three-level coding results, no new categories and relationships are found in the content of parents' educational expectations, cognition of expectations, and conditional guarantees. Therefore, it can be concluded that the relationship model between parents' educational

Table 3: Analysis of interview data of parents (open coding).

Excerpts of original data sentences	Initial concept	Category
Children have a correct outlook on life and values, to know how to respect others	A1 correct values	B1 guidance of values
Children cannot just pursue money, but do things useful to the country when they grow up	A2 being useful to the country	
No matter how brilliant the star is, it is packaged through some commercial means. It is through personal effort and talent that one can become a truly successful person	A5 work hard	B3 positive state
Self-discipline is more important in independent learning	A12 independence and consciousness	B7 self-discipline
The high expectations I have for my children sometimes put a lot of pressure on them, making myself and my family very anxious very often	A14 high expectations are prone to anxiety	B9 anxiety stress
Perhaps all parents have too high expectations for their children, which can cause some psychological pressure on the children	A15 high expectations bring pressure	
Double reduction is a good policy, which is beneficial to the physical and mental development of children	A24 political advantage	B13 national policy

Note. Due to the large number of coding contents, only the representative or special statements are selected as examples in this study.

Table 4: Analysis of children's interview data (partial).

Excerpts of original data sentences	Initial concept	Category
My mother seldom hits me but encourages me more	A1 positive encourage	B1 encourage education
Once I did not get good grades on the exam, my father encouraged me instead of blaming me. I felt a little sad because I did not try my best to learn; it was my problem	A2 self-reflection	
The high expectations my parents have for me are a great motivation. I don't want to live up to their expectations	A7 generate momentum	B4 transcend yourself
In some cases, my parents would let me try my best even though they knew I might not be able to do it. By trying, I did well every time, and things weren't that hard as I thought	A8 do your best	
My father doesn't ask me to study well; he wants me to stay happy and healthy by doing what I want to do in the future	A15 happiness and health	B7 life expectancy
Sometimes my teacher would give the parents some assignments, and my mother always did them very carefully	A20 work hard	B10 serious and self-disciplined
My mother insists on finishing her daily assignments, which greatly influences me	A21 stick to self-discipline	

Note. Due to the large number of coding contents, only the representative or special statements are selected as examples in this study.

Table 5: Analysis of parents' interview data.

Open code extraction category	Subcategory	Main category
B1 guidance of values B2 inner abundance B3 positive state B4 positive quality	C1 quality expectation	D1 what to expect
B5 emphasize learning B6 learning motivation B7 learning self-discipline B8 learning method	C2 learning expectation	
B9 anxiety and stress B10 progress leads	C3 anticipation effect	D2 expectation awareness
B11 deny the child B12 encourage to try	C4 education method	
B14 adjust mentality B15 parent occupation B16 parents' reflection B17 parent status B18 parental awareness	C5 parents	D3 condition guarantee
B19 words and deeds	C6 words and deeds	
B13 national policy	C7 national policy	D4 policy guarantee

Table 6: Analysis of children's interview data.

Open code extraction category	Subcategory	Main category
B1 encourage education		
B2 punishment education	C1 education method	
B5 emotional stress		D1 condition guarantee
B9 work patience	C2 teach by words and deeds	
B10 serious self-discipline		
B3 do your best	C3 breakthrough	D2 expectation effect
B4 transcend yourself		
B6 quality expectation		
B7 life expectation	C4 what to expect	D3 what to expect
B8 study well		

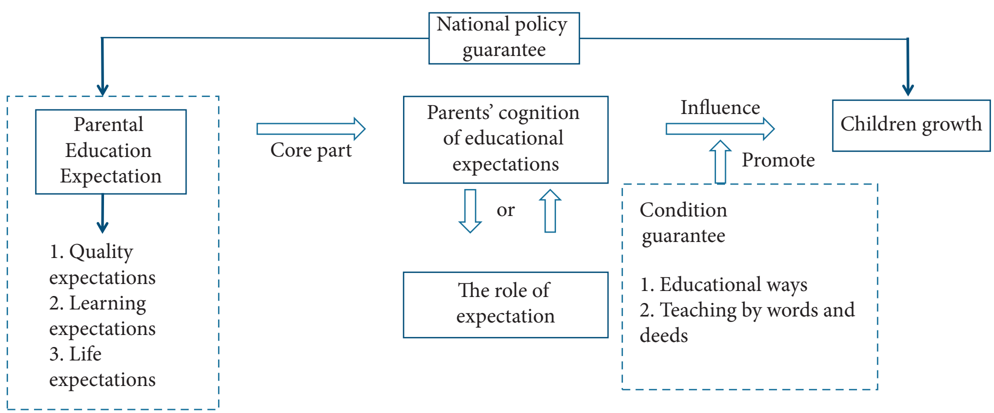

Figure 1: Parental expectation and children growth theory model diagram.

expectations and children's growth is theoretically saturated.

4. Results and Discussion

4.1. The Educational Expectations of the Parents of Elementary School Students Are Not Limited to Learning, But Are More Concerned with the Intrinsic Value of the Children's Development. The existing research on parents' educational expectations focuses more on the parents' expectations for their children's studies and future careers. Therefore, some scholars believe that parents' educational expectations present too many external instrumental purposes, but lack attention to internal values [5]. Perhaps because the study population was elementary school, the educational expectations of parents in this study showed unique characteristics of this age group. The results of the interviews with parents and children indicated that parents' educational expectations consisted of three main areas, which are also apparent from the figure.

4.1.1. Quality Expectations. Family education involves many aspects, but the most important thing is character education, which is how to behave [6]. In other words, it is the primary task of family education and the most fundamental and effective function of family education [7]. After a grounded analysis, the interviewees' expectations of children's quality mainly include four major aspects: guidance of values (correct outlook on life and values, not self-centered), inner enrichment (with love in the heart, pursuing the inner), positive state (working hard), and positive qualities (honest and trustworthy, willing to help others, filial piety to the elders, take responsibility). From this, we can see that in terms of the quality requirements for children, in addition to the recognized traditional virtues, parents have good expectations of their children's internal and external conditions. Moreover, parents attach great importance to the cultivation of their children's values. As one interviewee said, children should become useful to the country when they grow up, rather than just pursuing money or their enjoyment, or simply pursuing their dreams and goals.

4.1.2. Learning Expectations. Chinese parents generally have high expectations for their children's education and hope they will have better academic achievements [8]. The parents of contemporary elementary school students present two characteristics in terms of learning expectations. First, there are two different perspectives on "learning" itself. The first view believes that learning is very important, and therefore, the expectations for children's academic performance are very high. If the children achieve the goals expected by their parents, they will be rewarded; otherwise, they will be punished.

However, the second view is that parents do not consider learning a core task in elementary school. As the interviewees put it: elementary school students should not bear the pressure of learning. The second notable feature is that parents pay more attention to children's learning quality, including internal learning motivation, self-discipline in learning, and good learning methods.

4.1.3. Life Expectations. The children interviewed stated that the most impressive sentence their parents have ever said is as follows: what is most important is not to study well, but to engage in what they want to do in the future, to do what they want to do well, and to live a happy and healthy life. It can be seen that happiness and health are parents' expectations for their children's entire life. Compared with the past research literature, this is a characteristic of the new era of parental expectations for children. In the past literature, parents' expectations of children mainly focused on learning. This may be related to parents' educational level and family education literacy. In particular, the recently promulgated "Family Education Promotion Law of the People's Republic of China" clarifies the importance of family education from a legal perspective, which stipulates that the state and society provide guidance, support, and services for family education. It can be predicted that the implementation of these policies will further play a positive role in changing parents' concept of family education.

4.2. There Are Differences in the Perceptions of Educational Expectations between Parents and Children. The educational expectation is of great value, which itself is the goal to be pursued. In pursuing the goal, there is a strong inner motivation to achieve it. The parents' educational expectations of their children will be transformed into the children's internal drive, which will enhance their self-confidence. In the research of this article, it is found that parents perceived two effects of educational expectations: generating anxiety and stress or prompting progress. Parents believed that if expectations were too high, both parents and children would experience anxiety and stress, but parents also believe that educational expectations allow their children to stimulate their potential and transcend their limits. Just as the interviewee said, if you have higher requirements for your children, they can at least make progress. If there is no requirement, they may stop or even regress.

In other words, parents believe that educational expectations have both positive and negative effects. However, analysis of the children's interview data revealed that children generally perceived their parents' high expectations as encouraging rather than stressful. The children's stress is partly because parents have used inappropriate educational ways, rather than deriving from high expectations. This may be related to the age of the children. They are all primary students and are unclear about their potential and future. Parents' high expectations for their children help them become a better version of themselves. This high expectation is a huge stimulus and encouragement to the children. As one child interviewed said, my parents knew that I probably could not do it, but they would let me try. I think I have to do it well because this is an encouragement and urge to me. I did my best every time and did well, and things were not that bad as I thought.

4.3. Parents' Educational Expectations as a Guarantee of Conditions That Promote Children's Growth: Educational Methods and Teaching by Words and Deeds. If a child's growth falls short of parents' educational expectations, some parents do not actively think about the reasons but lower their expectations [9]. This study also found that even if parents think about the reasons, they overly believe that their children have intellectual differences with others, thus creating a gap, instead of reflecting on their level of education, methods, and whether they teach by words. Education methods are generally divided into encouragement education and punishment education. Encouragement education refers to parents emphasizing the importance of efforts and not making unnecessary comparisons, which will help their children grow. Punishment education is mainly reflected in parents' emotional out-of-control and beating and scolding education, which creates psychological pressure on children. Psychological research shows that too much psychological pressure will affect the healthy growth of children. Teaching by words and deeds is the basic principle of family education [10]. In interviews with children, it is found that the most important thing affecting children is the attitude and spirit of parents when they do something. This attitude and spirit are the fundamental factors for children to grow up gradually.

4.4. The National Education Policy Can Better Help Parents View Their Educational Expectations Rationally. Educational anxiety will lead to quick-witted behavior in education, and parents' unreasonable educational expectation is an inevitable result of educational anxiety [11]. There are many reasons for educational anxiety, especially the unfairness of education. This problem needs to be solved by the national governance, and individuals are powerless to do anything about it. The newly issued Opinions on Further Reducing the Burden of Homework and Off-Campus Training for Compulsory Education Students (the "double reduction") is a national policy to return to the essence of education. In interviews, elementary school students' parents generally believe that double reduction is a good policy to reduce their educational anxiety. At the same time, it also promotes their new thinking in raising children and readjusts their educational expectations for their children. It can be seen that parents' educational expectations are significantly related to the national education policy.

5. Conclusions

5.1. Research Conclusions. Based on grounded theory, this study elucidates the educational expectations of parents of elementary school students through the analysis of the data from the interviews with elementary school students and their parents. In terms of the relationship between parents' educational expectations and children's growth, the following conclusions are finally drawn.

Firstly, the educational expectations of the parents of elementary school students mainly include three main contents, namely quality expectations, learning expectations, and life expectations for their children. That is to say, in addition to expectations for children's learning, parents of elementary school students today also have expectations in terms of quality and life expectations.

Secondly, different "cognitions" of educational expectations lead to differences in parents' behavior, which in turn affects children's growth. If parents believe that higher educational expectations are better, they tend to place high expectations on their children's education, which will stimulate their children's growth. Conversely, if they think that educational expectations are prone to stress and anxiety, they will lower expectations, and the child will naturally lower his or her self-expectations.

Thirdly, parents' educational methods and teaching by words and deeds are the guarantees of parents' educational expectations, which also promote children's growth. The deviation of children's growth from parents' educational expectations is not because of excessive parents' educational expectations. In fact, it is because parents use inappropriate educational methods to achieve their educational expectations, which leads to psychological pressure on children. This psychological pressure makes children tired of learning and rebellious.

Lastly, the national education policy is a fundamental guarantee for promoting the relationship between parents' educational expectations and children's growth. The research found that parents' educational expectations are closely related to the national education policy. To a certain extent, the national education policy provides parents with correct guidance for family education and also provides institutional guarantees, thus greatly affecting parents' educational expectations and making it possible for children to grow up healthily.

5.2. Theoretical Findings. Based on the grounded analysis of the content of parents' educational expectations, this study concludes that parents' educational expectations are not limited to academic expectations, but also include quality expectations and life expectations. This expands previous research studies that have been limited to academic expectations. In addition, previous studies have different views when exploring the relationship variables between parents' educational expectations and children's growth. Some researchers believe that parents' expectations need to be transformed into expectations that children identify with to promote children's growth [2]. This study believes that if parents use appropriate educational methods and teach by words and deeds by improving their literacy, parents' educational expectations will greatly contribute to children's growth. Therefore, the theoretical contribution of this study is to add new content for the relationship between parents' educational expectations and children's growth and provide a new research perspective [12].

5.3. Practical Enlightenment. According to the research of this study, we should pay attention to the following points in family education:

Firstly, parents should maintain high expectations for children. Parents' educational expectations are of great significance to their children. They are not only the driving force for children's growth but also the guide to stimulate their potential [13].

Secondly, parents should adopt a developmental mindset, rather than making a simple attribution and lowering expectations. When there is a gap between children's growth and parents' educational expectations, parents should think about whether to use encouragement education or stress education, whether to give children internal strength or increase emotional pressure, instead of making simple attributions and lowering expectations for the children [14].

Thirdly, parents should strengthen self-reflection. Parents need to improve their educational concepts, emotional management, behavior habits, life, and other qualities and consider whether they can influence their children by words and deeds.

5.4. Research Limitations and Future Research Directions. The relationship between parents' educational expectations [9] and children's growth is based on a small sample in this paper's model, and the sample is mostly from urban schools [15]. More research is needed to see whether this model applies to specific family groups. Second, children are perplexed by their parents' expectations, according to the in-depth interviews. Their parents, for example, expect them to contribute to the country, but the children have no idea how to do so. Parents generally expect their children to be self-disciplined when it comes to learning, but they also do not know how to raise their children in specific ways [16]. This phenomenon has not been explored in depth in this study. Finally, this study came to the important conclusion that national education policy has a significant impact on parents' educational expectations; however, what new relationship does this impact have with children's development? Due to the study's short length and duration, more research on this article is not possible. We will still be able to conduct in-depth research in the future.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author does not have any possible conflicts of interest.

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Research Article

Application and Comparison of Multiple Machine Learning Models in Finance

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Accurate and effective financial data analysis is very important for investors to avoid risks and formulate profitable investment strategies. Therefore, the analysis of financial data has important research significance. However, the financial market is a complex nonlinear dynamic system affected by many factors. It is very challenging to analyze the financial data according to the obtained information. Among them, stock selection is the most typical financial data mining problem. The core of stock selection is to design a systematic scoring mechanism to quantitatively score stocks so as to more intuitively reflect the investment value of stocks. The scoring mechanism is based on the assumption that stocks with higher scores have higher investment value and stocks with lower scores have lower investment value. The stock selection model proposed in this paper mainly includes two steps: stock prediction and stock scoring. First, construct stock predictors and use machine learning forecasting methods to predict the future price of each stock. Second, construct a stock scoring mechanism to evaluate each stock through the predictive factors and financial factors in the previous step. Finally, select high-scoring stocks and make equal-weight investments. This paper applies the model to the empirical study of the A-share market, verifies its feasibility and effectiveness, and makes a systematic comparison with other benchmark models.

1. Introduction

With the development of the market economy, the issuance and trading of stocks occurred, and both promoted the development of the market economy. In recent years, stocks have shown their tenacious vitality, and the stock market has gradually become an indispensable part of the entire financial industry, especially the securities industry. In order to develop the national economy better and faster, as my country continues to enter the deep water zone of reforms, the reforms in the financial sector are gradually deepening [1]. Predicting the development of stocks has always been the direction of research and exploration by scholars from all walks of life. Predicting the development of stocks is a branch of prediction. The premise is to use scientific methods and methods, and it is necessary to know the development laws of financial markets, understand economics, and fully grasp the law of development of the financial market and the current stage of development [2].

Faced with confusing, high-dimensional, and huge amounts of historical stock information, it is a reasonable and efficient way to analyze and process with the help of computers, which frees stock analysts from tedious work and concentrates on analyzing key issues [3]. The high-speed processing capability of the computer makes it possible to provide customers with more comprehensive and accurate forecasts in a short period of time. In addition, algorithms can provide insights into the forecasting problem from novel perspectives to achieve better forecasting results, which are beyond the reach of human analysis. Model algorithms such as machine learning and deep learning are suitable for the analysis of high-dimensional big data, and the use of computers to customize auxiliary software for stock forecasting for different service objects has become a research hotspot [4]. This paper will combine neural networks and support vector machines, two of the most widely used machine learning models, and propose improvements to provide novel solutions to problems such as model mixing and stock forecasting [5]. According to the existing stock analysis and prediction methods, the participation of the whole people can be maximized, and it is not necessary to have sufficient financial expertise to participate in stock investment. For research topics with special properties such as time series and high-dimensional stock historical data, many forecasting methods can be used for reference [6]. Therefore, the research topic of stock forecasting has very important significance from both theoretical and application perspectives and meets the current needs.

2. Preliminary Study

2.1. Problem Definition. The total data set $D=\{X, Y\}$ is composed of the input factor X and the real label Y corresponding to the input factor X, and the prediction result Y is obtained by using the model $F(\cdot)$ to predict the data set D. When designing a specific prediction scheme, the input factor X and label Y can be differentiated according to the prediction model $F(\cdot)$ and the purpose of prediction. Therefore, the input factor X can be time series data, text data, binary features, and so on, and the label Y can be a specific value, classification result, and so on.

Obviously, financial stock forecasting is a complex problem, which has the following five characteristics: (1) it is appropriate to use machine learning to analyze and predict financial stocks., and the input sources for stock prediction are huge, high-dimensional, and heterogeneous, and machine learning algorithms are particularly good at processing such data [7]; (2) indirect factors such as real-time data on the Internet and public sentiment will also affect the prediction results; (3) when considering numerical data as an input feature, the basic transaction data and the technical indicators calculated from the basic transaction data are huge and need to be selected, and in addition, the two features may affect each other; (4) each stock has its own specific development law, and the trained model algorithm is not necessarily applicable to the data sets of other stocks; and (5) for the prediction output, it can be divided into classification prediction and regression prediction according to the purpose of prediction. Classification and regression forecasts not only reflect trends and stock price forecasts but also provide new ideas for investment strategies and price reversal points [8].

2.2. BP Neural Network. The neural network model is currently the most widely used neural network. At the same time, the neural network has the ability to predict only after training and learning and can adapt to the prediction requirements, obtain the structure of learning knowledge, and map the nonlinearity to linear functions [9]. The main structure diagram and flowchart are shown in Figures 1 and 2.

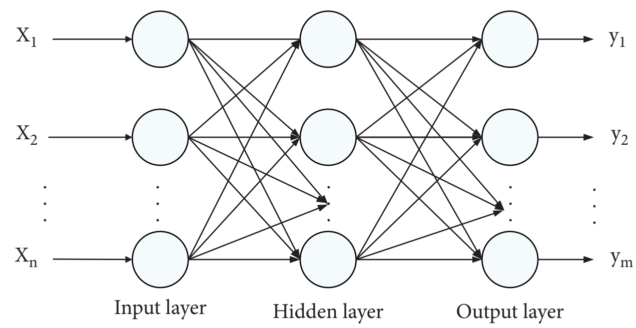

Figure 1: BP neural network structure diagram.

When the BP neural network predicts stocks, the time series $i\{X\}$ is regarded as the input value of the input layer, and a part of it is selected for training. The price $\{Y_i\}$ obtained from the training result is compared with the actual price and adjusted by feedback. After multiple iterations, the prediction model is obtained, and then the price of $a+b+c$ $(c \geq 1)$ at a certain time in the future is predicted. The nonlinear relationship of the price Y_{a+b+c} time series at the predicted time can be expressed by the following formula:

$$X_{a+b+c} = f\left(X_a, X_{a+1}, \ldots\ldots, X_{a+b}\right). \tag{1}$$

The fitting model f is obtained through the training set time series $X_a + X_b + \cdots + X_{a+b}$, and the unvalued value is predicted from this.

2.3. Support Vector Machine Regression. Support vector machine (SVM) was first proposed by Vapnik et al. [10] Based on the "structural risk minimization" criterion, the optimal hyperplane is constructed to separate the two types of samples to the greatest extent. Support vector machine regression (SVR) is an extension of SVM [11]. The basic principle of SVR is similar to SVM, but its purpose is different. It aims to construct an optimal classification plane to minimize the error of all samples from the classification plane [12].

There are n training samples, where x_i is the input variable and y_i is the output variable. SVR can be regarded as a quadratic programming problem, as shown in the following equation:

$$\begin{aligned} &\min \frac{1}{2}\|w\|^2, \\ &\text{subject to}\left\| y_i - \left(w \cdot x_i + b\right)\right\| < \varepsilon, \quad i = 1, \ldots, n, \end{aligned} \tag{2}$$

where ξ represents the boundary of the prediction error.

In order to ensure the generalization ability of the model, slack variables ξ_i and ξ_i^* are introduced to modify equation (2), namely,

$$\min \frac{1}{2}\|w\|^2 + C\sum_{i=1}^{n}\left(\xi_i + \xi_i^*\right), \tag{3}$$

$$\text{subject to}\begin{cases} y_i - w, x_i - b \leq \varepsilon + \xi_i, \\ w, x_i + b - y_i \leq \varepsilon + \xi_i^*, \\ \xi_i, \xi_i^* \geq 0, \end{cases} \tag{4}$$

where C is the penalty factor, which is the maximum tolerance error.

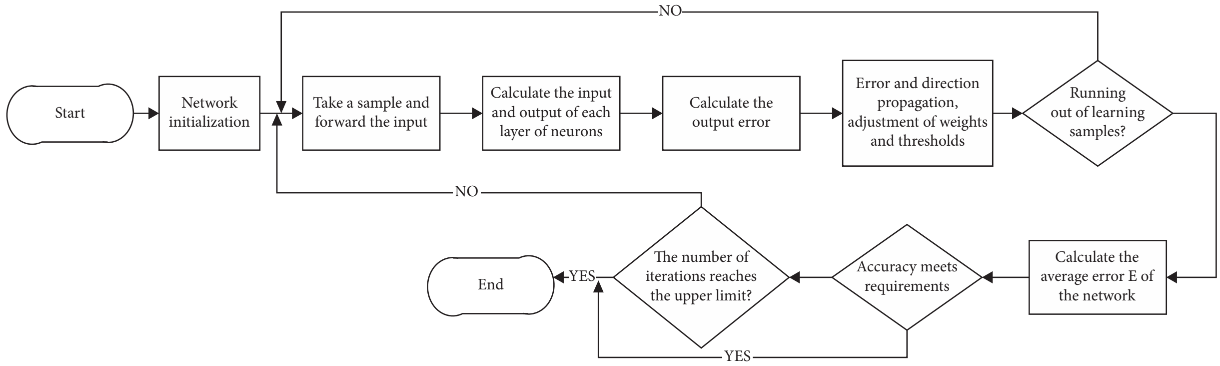

Figure 2: Flow chart of BP neural network implementation.

In order to solve equations (3) and (4), the Lagrange function is introduced and transformed into a dual problem as follows:

$$L = \frac{1}{2}\|w\|^2 + C\sum_{i=1}^{n}\left(\xi_i + \xi_i^*\right) - \sum_{i}^{n}\lambda_i\left(\varepsilon + \xi_i - y_i + w, x_i + b\right) - \sum_{i}^{n}\lambda_i^*\left(\varepsilon + \xi_i^* + y_i - w, x_i - b\right) - \sum_{i=1}^{n}\left(\eta_i\xi_i + \eta_i^*\xi_i^*\right), \in \eta_i, \eta_i^*, \xi_i, \xi_i^* \geq 0. \tag{5}$$

Solve the Lagrange equation and get the optimal solution w^* and b^* as follows:

$$\begin{aligned} w^* &= \sum_{i}^{n}\left(\lambda_i - \lambda_i^*\right)x_i, \\ b^* &= y_i - w^*, x_i - \varepsilon, 0 \leq \lambda_i \leq C, i = 1, \ldots, n, \\ b^* &= y_i - w^*, x_i + \varepsilon, 0 \leq \lambda_i^* \leq C, i = 1, \ldots, n. \end{aligned} \tag{6}$$

3. The Design of the Financial Stock Selection Model Based on Machine Learning Models

3.1. Stock Prediction Model Framework. The stock selection model proposed in this article mainly includes two steps: stock prediction (used to construct predictive factors) and stock scoring (used to evaluate stock value) [13–15]. The overall framework is shown in Figure 3.

3.2. Financial Stock Forecast and Scoring

3.2.1. Financial Stock Forecast. In order to construct predictors, we predict the returns of all stocks. In the period of t, use $z_{i,k,t}\,(k = 1, 2, \ldots, 17)$ transaction data to predict the stock price in period t+1 as follows [13]:

$$\widehat{P}_{i,t+1} = f\left(z_{i,1,t}, z_{i,2,t}, \ldots, z_{i,17,t}\right), \tag{7}$$

where $\widehat{P}_{i,t+1}$ is the predicted price of stock i in period $t+1$ and $z_{i,k,t}$ is the k-th transaction data of stock i in period t. A total of 17 trading factors are used to predict the future price of stocks. The 17 trading factors can be roughly divided into 4 categories. Volume and price factors include the previous day's closing price, trading volume, opening price, average price, closing price, lowest price, turnover, and highest price [14]. Valuation factors include P/B ratio, P/B ratio, P/E ratio, and P/S ratio [15]. Risk factors include ups and downs of yuan, ups and downs, and turnover rate. Scale factors include total market capitalization and total equity. The predicted stock price $\widehat{P}_{i,t+1}$ is transformed into the predicted stock return through equation (10):

$$\widehat{R}_{i,t+1} = \frac{\widehat{P}_{i,t+1} - P_{i,t}}{P_{i,t}}, \tag{8}$$

where $\widehat{R}_{i,1}$ represents the predicted return of stock i in the period. Furthermore, normalize $\widehat{R}_{i,t+1}$ to obtain $\widehat{Y}_{i,t+1}$, and the process is shown in equation (11). $\widehat{Y}_{i,t+1}$ will be used as a predictor for the stock scoring in the second step.

$$\widehat{Y}_{i,t+1} = \frac{\widehat{R}_{i,t+1} - \widehat{R}_{t+1}}{\widehat{D}_{t+1}}, \tag{9}$$

where $\bar{\widehat{R}}_i = \sum_{x\in 1}^{N}\widehat{R}_{i,t}/N$ is the average value of the predictor and $\widehat{D}_t = \sqrt{\sum_{i=1}^{X}(\widehat{R}_{i,t} - \bar{\widehat{R}}_t)^2/N}$ is the standard deviation of the predictor, where N is the number of stocks.

3.2.2. Financial Stock Scoring. In addition to predictive factors, financial factors $V_{i,j,r}\,(j = 1, \ldots, 12)$ have also been introduced into our stock selection model. These factors are widely used in existing stock selection models, and they usually reflect the company's operating conditions. For example, ROE usually reflects the company's profitability; debt to equity ratio (DE) usually reflects the company's bar ratio; current ratio (CR) usually reflects the company's liquidity; and inventory turnover rate (ITR) usually reflects the company's operating efficiency and operating income [16]. The growth rate OIG usually reflects the company's growth and so on. As with forecasted earnings, standardize them as follows [17]:

$$\frac{Y_{i,j,t} = V_{i,j,t} - \bar{V}_{j,t}}{D_{j,t}}, \tag{10}$$

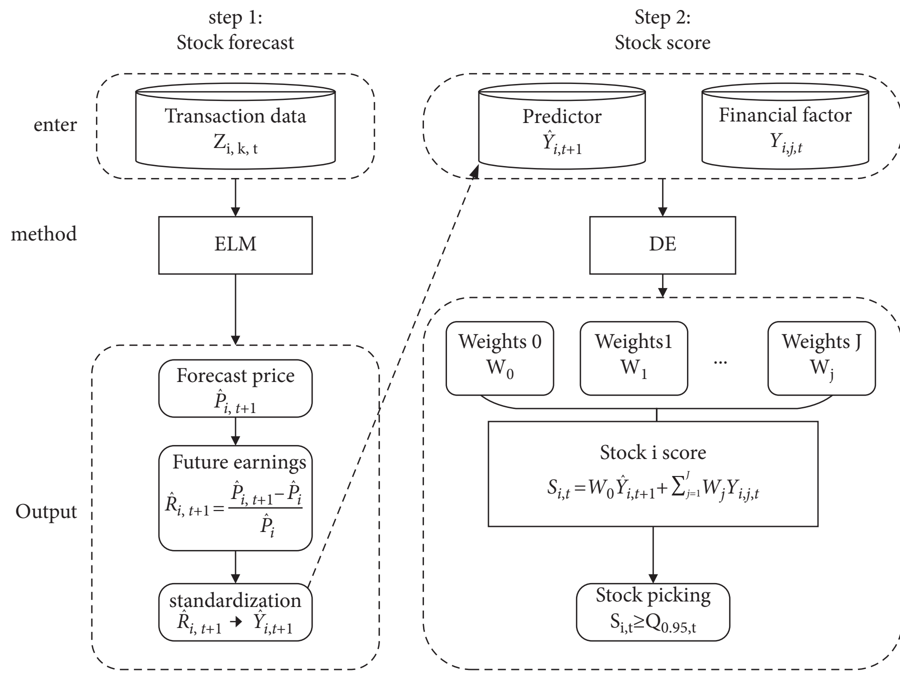

Figure 3: Framework diagram of the stock selection model.

where $\bar{V}_{j,t} = \sum_{i=1}^{N} V_{i,j,j}/N$ is the average value of financial factors and $D_{j,t} = \sqrt{\sum_{i=1}^{N} (V_{t,j,t} - \bar{V}_{j,t,})^2/N}$ is the standard deviation of the financial factor, where N is the number of stocks.

The stock's i score in the period of t, $s_{i,t}$, can be described as a linear combination of predictive factors and financial factors as follows:

$$s_{i,t} = W_0 \widehat{Y}_{i,t+1} + \sum_{j=1}^{J} W_j Y_{i,j,t}, \tag{11}$$

where W_0 represents the weight of the predictive factor, W_j represents the weight of the j financial factor, and $s_{i,t}$ represents the comprehensive score of the stock in the period.

Each stock is sorted according to its comprehensive score from high to low, denoting $r_{i,j} \in \{1, 2, \ldots, N\}$, if $s_{i,t} \geq s_{k,t}$, then $r_{i,1} \leq r_{k,}$ where $i, k \in \{1, 2, \ldots, N\}$ represents any two separate stocks. In each period, the top m stocks are selected for equal-weight investment. The portfolio returns are as follows:

$$\begin{aligned} \overline{R}_{t+1} &= \frac{1}{m} \sum_{r_{i,j}=1}^{m} R_{t+1}\left(r_{i,t}\right), \\ r_{i,t} &= 1, 2, \ldots, m, \end{aligned} \tag{12}$$

where m is the number of stocks that the investor hopes to choose and $R_{t+1}(r_{i,t})$ is the t return of the stocks selected during the period sorting in period $t+1$. R_{t+1} is the average return of stocks selected according to the model in $t+1$.

This research introduces Spread as the objective function (fitness function) of the model. The objective function (fitness function) is defined as the long-short portfolio return of the top stocks in the t period comprehensive score and the stocks after the m period comprehensive score.

$$\begin{aligned} \min_{w_j} F &= -\frac{1}{T} \sum_{t=1}^{T} \text{Spread}_t, \\ \text{Spread}_t &= \frac{\sum_{r_{i,t=1}}^{m} R_{t+1}\left(r_{i,t}\right) - \sum_{r_{i,t=N-m+1}}^{N} R_{t+1}\left(r_{i,t}\right)}{m}. \end{aligned} \tag{13}$$

3.3. Evaluation Indicator. Root mean square error (RMSE), mean absolute percentage error (MAPE), and directional statistics (D-STAT) are often used to evaluate the effectiveness of prediction models. This article also uses the above three indicators to evaluate the effectiveness of various prediction models in this article as follows [18]:

$$\begin{aligned} RMSE &= \sqrt{\frac{1}{N \cdot T'} \sum_{i=1}^{N} \sum_{l=1}^{\left(P_{i,t} - \widehat{P}_{i,t}\right)^2}}, \\ MAPE &= \frac{1}{N \cdot T'} \sum_{i=1}^{N} \sum_{t=1}^{T'} \left| \frac{P_{i,1} - \widehat{P}_{i,t}}{P_{i,t}} \right|, \\ Dstat &= \frac{1}{N \cdot T'} \sum_{i=1}^{N} \sum_{t=1}^{T'} a_{i,t}, \end{aligned} \tag{14}$$

where T is the number of test periods, N is the number of stocks, $P_{i,t}$ is the price of stock i in period t, $\widehat{P}_{i,t}$ is the predicted price of the stock, and when $(P_{i,t} - P_{i,t-1})(\widehat{P}_{i,t} - P_{i,t-1}) > 0$, $a_{i,t} = 1$; otherwise it is 0. In addition, the running time of the model is also an important indicator for evaluating the performance of the model. It will cover the entire time of the training period and the test period.

Choosing high-quality stocks for equal-weight investment means constructing an equal-weight investment portfolio. Portfolio income can most intuitively reflect the effectiveness of the stock selection model. The higher the portfolio return, the better the effect of the stock selection model. Therefore, this paper adopts the average return of all investment portfolios during the test period as one of the evaluation indicators of the stock selection model. In addition, portfolio risk is also a key concern. SharpeRatio is a commonly used indicator to describe portfolio risk. This article also uses SharpeRatio as one of the evaluation indicators of the stock selection model. The specific calculation formula is as follows [19]:

$$AR = \frac{1}{T'} \sum_{t=1}^{T'} \bar{R}_{t+1} \text{ , Sharpe Ratio} = \frac{E\left[\bar{R}_t - R_i^f\right]}{\sigma}. \tag{15}$$

where $\overline{R}_1$ is the average return of the portfolio in the t period, that is, the average value of the strategy return; R_i^f is the risk-free return in the t period; $E[\underline{R}_t - R_i^f]$ is the expectation; and σ is the portfolio volatility, that is, the strategy return.

3.4. Hyperparameter Setting. All parameters involved in the model and benchmark model proposed in this paper refer to previous studies, as shown in Table 1. Regardless of whether it is an optimization model or a prediction model, there are random variables or parameters, and different optimization values will be generated every time the model is run (the output result cannot be guaranteed to be the optimal result). Therefore, all models are run 30 times for each case, and their average value is used as the final output result.

4. Experimental Test and Result Comparison

4.1. Experimental Data Set. The trading volume and total market value of China's A-share market in the global financial market are increasing day by day, and its status is increasing day by day. Therefore, the A-share band field is selected as the experimental sample of this article. There are a total of 2,473 stocks as candidate stocks for the investment portfolio, which excludes financial industry stocks with different balance sheet structures and specially processed stocks ST that may be unstable. In the existing stock forecasting models, this chapter will introduce the acquisition, processing, and cleaning of data sources from two aspects of stock index data and text data. Among them, stock index data refers to data related to stock trading. The text data mainly consists of news data. The trading data used for stock forecasting and the financial data of stock scoring are all quarterly data, and they all come from the Wind database.

4.2. Benchmark Model Comparison. As shown in Table 2, this article introduces a variety of benchmark models, including different prediction models (marked as M1), different factorial designs (marked as M2), different optimization algorithms (marked as M3), and different fitness functions (marked as M4). Among them, M0 is the stock selection model proposed in this article. Next, we will introduce the construction methods of various benchmark models in detail.

In each benchmark method, in order to ensure the fairness of comparison, each type of benchmark model only changes its unique variable. For type M1, BP neural network (BPNN) and support vector machine regression (SVR) are two classic forecasting models, which are widely used in stock forecasting, investment portfolio, and stock selection research. Therefore, this article will introduce these two prediction models as the benchmark model. For type M2, the model proposed in this paper contains two types of factors, namely, basic factors and predictive factors, which are denoted as A0. Two new designs are now introduced as the benchmark model of this article. Design A1 means that only financial factors are considered but not predictive factors, and design A2 means that only predictive factors are considered but not financial factors. For type M3, the more popular intelligent optimization algorithm in the stock selection model is introduced as the benchmark model of this article, namely, genetic algorithm GA and particle swarm algorithm PSO. For type M4, in the stock selection model based on the intelligent optimization algorithm, four commonly used optimization objective functions (fitness functions) are used as the benchmark model of this article, namely, information coefficient (IC), equity (CR), long-short combination winning rate (IFHR), and absolute win rate (WIN).

$$IC = -\frac{1}{T} \sum_{t=1}^{T} \frac{\operatorname{cov}\left(r_{i,t,}, r'_{i,t}\right)}{\sqrt{\operatorname{var}\left(r_{i,t}\right)\operatorname{var}\left(r'_{i,t}\right)}},$$

$$CR = -\prod_{i=1}^{T}\left(1 + \bar{R}_{t+1}\right),$$

$$IFHR = -\frac{1}{T} \sum_{t=1}^{T} \left(\frac{\sum_{r_{i,t}=1}^{m} \operatorname{sgn}\left(R_{t+1}\left(r_{i,t}\right) - M_{t+1}\right)}{2m} - \frac{\sum_{r_{i,t}=N-m+1}^{N} \operatorname{sgn}\left(R_{t+1}\left(r_{i,t}\right) - M_{i+1}\right)}{2m} \right),$$

$$WIN = -\frac{1}{T} \sum_{t=1}^{T\sum\left(\bar{R}_{t+1}\right)} sgn, \tag{16}$$

where T is the number of training periods, $r_{i,t}$ is the ranking of stock i in the t-th period, $r_{i,t}$ is the stock's income ranking in $t+1$ period, $\operatorname{cov}(\cdot)$ is the covariance, $\operatorname{var}(\cdot)$ is the variance, m is to select the number of stocks, and $\overline{R}_{t+1}$ is the average return of the stock selection strategy in the $t+1$ period. It outputs 1 when it is $x > 0$; otherwise, it outputs 0. See Table 1 for benchmark model design.

Table 1: Parameter settings of this model and benchmark model.

Optimization	Parameter	Value	Method of prediction	Parameter	Value
	P	30		N	$0.1*N$_train
DE	Cr	0.5	ELM	TF	sig
	F	0.6		n	10
	P	50		ep	3,000
GA	cr	0.6	BPNN	lr	0.1
	mr	0.5		mc	0.4
	P	40		K	RBF
PSO	$c1 = c2$	1.495	SVR	r	$\{2^{-15}, 2^{-13}, \ldots, 2^{13}, \ldots, 2^{15}\}$
	wn	[0.4, 0.9]		C	$\{2^{-15}, 2^{-13}, \ldots, 2^{13}, \ldots, 2^{15}\}$

Note: γ and C are traversed from the grid of $\{2^{-15}, 2^{-13}, \ldots, 2^{13}, 2^{15}\}$ to obtain values. N_train is the number of training periods of the extreme learning machine. For other parameter descriptions, please refer to the description of symbols and abbreviations.

Table 2: Benchmark model design.

Type	Describe	Predictive model	Factorial design	Optimization	Fitness function
M0	Stock selection model	ELM	A0	DE	Spread
M1	Benchmark model: different forecasting models	BPNN	A0	DE	Spread
		SVR	A0	DE	Spread
M2	Benchmark model: different factorial designs	ELM	A1	DE	Spread
		ELM	A2	DE	Spread
M3	Benchmark model: different optimization algorithms	ELM	A0	PSO	Spread
		ELM	A0	GA	Spread
M4	Benchmark model: different fitness functions	ELM	A0	DE	IC
		ELM	A0	DE	CR
		ELM	A0	DE	IFHR
		ELM	A0	DE	WIN

4.2.1. Comparison of Different Prediction Models (M1). When constructing predictors, this article uses the extreme learning machine ELM to predict stock prices. In order to prove the effectiveness of ELM in stock forecasting, two classic forecasting methods, BP neural network (BPNN) and support vector machine regression (SVR), are introduced as benchmark models. Table 3 shows the prediction results. Among them, Prob.(R1) is the probability that the stock selection model of this article will have a higher quarterly return than the quarterly earnings of R1; Prob.(R2) is the probability that the quarterly earnings of the stock selection model of this article will be higher than the quarterly earnings of R2; and Max. is the average value of the maximum return of the stock selection model of this article; Min. is the average value of the minimum return of the stock selection model of this article; and HitRate represents the probability of the model obtaining a positive return [20].

As shown in module A in Table 3, the stock selection model using ELM performs more prominently in AR, SharpeRatio, Prob.(R1), Prob.(R2), and HitRatio. At the same time, the SVR stock selection model has achieved a little advantage in Max. and Min. while the stock selection model of BPNN is at a disadvantage in any evaluation index. This shows that the predictive factors constructed by ELM can better assist stock selection decisions. In order to statistically prove that the stock selection model using ELM is significantly better than other benchmark models, this section tests each benchmark model. The process is as follows: first, the normality test is performed on each model, and the normality test is the prerequisite for the test. Second, construct a null hypothesis, H0: the AR of the stock selection model using ELM is significantly lower than other benchmark models. According to module B, all models pass the

Table 3: Comparison results of different forecasting methods in the stock selection model.

Model	ELM	BPNN	SVR
Module A: performance of stock-picking model			
AR	0.0998	0.0877	0.0799
SharpeRatio	0.4054	0.2997	0.3049
Max.	0.4199	0.4089	0.4278
Min.	−0.3178	−0.3203	−0.3049
Prob.(R1)	0.6554	0.4712	0.5083
Prob.(R2)	0.7831	0.7500	0.7521
HitRatio	0.7603	0.7580	0.5813
Module B: t test ($H0$: $AR_{ELM} \leq AR_{\text{Benchmark}}$)			
Positive test (p value)	0.3121	0.2014	0.4179
t-stat	NA	18.1433	13.2240
p value	NA	<0.0001	<0.0001
Module C: stock forecast			
Computing time	60.1222	16,100.2541	32,399.8999
D-STAT	0.5148	0.4997	0.4978
MAPE	0.2189	0.2578	0.4001
RMSE	18.9997	32.2359	44.8972
Module D: DM test (H0: the prediction result based on the benchmark model is better than the prediction result based on ELM)			
DM-STAT	NA	−17.2012	−5.001
p value	NA	<0.0001	<0.0001

normality test, and the values of all models are less than 5%. It shows that at the 95% confidence level, the stock selection model based on ELM is better than the benchmark model. This proves that the predictive factors constructed by ELM can better assist stock selection decision-making.

Module C shows the evaluation indicators of all forecasting methods. Obviously, the method of using ELM to predict stock prices crushes all benchmark models in computing time, directional accuracy D-STAT, prediction accuracy MAPE, and RMSE. In the research of this article, ELM has more prominent predictive abilities. Similarly, in order to statistically prove that the prediction results based on the extreme learning machine ELM are significantly better than other benchmark models, this section conducts the Diebold–Mariano test (DM test) on each benchmark model. The process is as follows: construct a null hypothesis, H0: the prediction result based on ELM is significantly lower than the prediction result based on the benchmark model. The DM test results are shown in module D in Table 3. All values are less than 5%, indicating that the prediction results based on ELM are better than the benchmark model at the 95% confidence level. This proves that ELM has a stronger predictive ability. It can be seen that the predictor based on ELM structure can better assist stock selection decision-making.

4.2.2. *Comparison of Different Factorial Designs (M3).*

The innovation of the stock selection model proposed in this paper is the use of predictive factors and financial factors to evaluate the value of stocks. The predictive factors contain the future information of the stock market, and the basic factors contain historical information of the stock. In order to prove the effectiveness of this innovative design, the proposed stock selection model A0 is compared with the benchmark model A1 and the benchmark model A2 (as shown in Table 4). Among them, the benchmark model A1 only uses basic factors, similar to the traditional stock selection model, for which refer to the research done by Huang, and the benchmark model A2 only uses predictive factors, for which refer to the research done by Huang and Quah.

Table 4 shows the relevant results. At the same time, the A0 stock selection model has achieved outstanding performance in AR, SharpeRatio, Min., and Prob.(R1). However, only the A1 stock selection model and the A2 stock selection model have no outstanding performance in the various evaluation indicators. In order to statistically prove that the stock selection model using A0 is significantly better than other benchmark models, this section tests each benchmark model. The process is as follows: first, the normality test is performed on each model, and the normality test is the prerequisite for the test. Secondly, construct a null hypothesis, H0: the average return AR of the stock selection model A0 using predictive factors and financial factors is significantly lower than other benchmark models. According to module B, all models pass the normality test, and the values of all models are less than 5%. It shows that under the 95% confidence level, the stock selection model A0 using predictive factors and financial factors is better than other benchmark models. This proves that adding predictive factors can better assist stock selection decisions, and financial factors are equally important.

Table 4: Comparison results of different factorial designs in the stock selection model.

Model	A0	A1	A2	R1	R2
Module A: model performance					
AR	0.1102	0.0765	0.0799	0.8403	0.0398
SharpeRatio	0.4010	0.2997	0.3012	0.2988	0.1798
Max.	0.4587	0.4099	0.4010	0.3789	0.3594
Min.	−0.2998	−0.3201	−0.3587	−0.3099	−0.3178
Prob.(R1)	0.6549	0.4378	0.5001	NA	0.0000
Prob.(R2)	0.8001	0.7603	0.7554	1.0000	NA
HitRatio	0.7602	0.7812	0.7399	0.7849	0.5645
Module B: t-test ($H0$: $AR_{DF} \leq AR_{\text{Benchmark}}$)					
Normality test (p value)	0.2998	0.0489	0.3379	NA	NA
t stat	NA	20.5879	14.1339	25.8999	57.0004
p value	NA	<0.0001	<0.0001	<0.0001	<0.0001

4.2.3. *Comparison of Different Optimization Algorithms (M3).*

In this paper, the differential evolution algorithm is used to optimize the weights of various factors. In order to prove the effectiveness of DE, the classic genetic algorithm GA and particle swarm algorithm PSO are set as the benchmark model. As shown in Table 5, during the training and testing period, the DE stock selection model used in this paper is superior in average return AR and SharpeRatio, which not only shows that DE algorithm can better assist stock selection decision-making but also shows that the algorithm can achieve the best performance. The optimized factor weights have stronger generalization ability than the benchmark model. In order to statistically prove that the stock selection model adopted is significantly better than other benchmark models, this section tests each benchmark model. The process is as follows: first, the normality test is performed on each model, and the normality test is the prerequisite for the test. Secondly, construct a null hypothesis, H0: the AR of the stock selection model using DE is significantly lower than other benchmark models. As shown in the module, all models passed the normality test, and the values of all models were less than 5%. It shows that under the 95% confidence level, the DE-based stock selection model is better than other benchmark models. Thus, it is statistically proved that the differential evolution algorithm can better assist the stock selection decision-making.

4.2.4. *Comparison of Different Fitness Functions (M4).*

In this paper, the Spread fitness function (old standard han number) is used to make stock selection decisions, and four different fitness functions such as IC, CR, IFHR, and WIN are now used as benchmark models. The results are shown in Table 6. The stock selection model using the Spread fitness function has outstanding performance in average return AR and Sharpe Ratio. The stock selection model using the Spread fitness function can better assist stock selection decisions. In

Table 5: Comparison results of different optimization algorithms in the stock selection model.

Model	Training set		Test set		t-test ($H0$: $AR_{DF} \leq AR_{\text{Benchmark}}$)		
	AR	SharpRatio	AR	SharpRatio	Normality test (p value)	t-stat	p value
DE	0.1201	0.1311	0.1078	0.3644	0.2988	NA	NA
PSO	0.1887	0.1088	0.1244	0.3577	0.4999	3.7994	0.0002
GA	0.1001	0.1022	0.1012	0.3578	0.1994	4.3829	<0.0001

Table 6: The comparison result of the fitness function in the stock selection model is the difference.

Model	Spread	IC	CR	IFHR	WIN
Module A: model performance					
AR	0.1109	0.0812	0.0899	0.1135	0.0898
SharpeRatio	0.3789	0.2978	0.3576	0.3477	0.3396
Module: inspection (H0: $AR_{\text{Sprear}} \leq AR_{\text{Benchmark}}$)					
Normality test (p value)	0.2997	0.3889	0.1299	0.3751	0.4999
t-stat	NA	18.4436	19.1324	3.1162	7.1124
p value	NA	<0.0001	<0.0001	0.0013	<0.0001

order to statistically prove that the stock selection model using Spread is significantly better than other benchmark models, this section tests each benchmark model. The process is as follows: First, the Han-state test is performed on each model, and the normality test is the prerequisite for the test. Second, construct a null hypothesis, H0: the average return AR of Spread's stock selection model is significantly lower than other benchmark models. According to the module, all models pass the normality test, and the values of all models are less than 5%. This shows that at the 95% confidence level, the stock selection model based on Spread is better than other benchmark models. Thus, it is statistically proved that the stock selection model using the Spread fitness function can better assist stock selection decision-making.

5. Conclusion

This paper uses two machine learning models, neural network and support vector machine, to predict stock prices and conduct empirical research on China's A-share market. The results show that the machine learning model adopted in this paper has obvious advantages in terms of ROI and model robustness. The returns of portfolios constructed using the stock selection model proposed in this paper are much higher than the average market performance (i.e., an equal-weighted portfolio of all stocks) and the China A-share index. Notably, in model optimization, predictors were given higher weights, suggesting that stock predictors play an important role in stock selection. This also supports the new idea that introducing stock predictors can improve stock selection decisions. Especially when comparing the designs of different factors, the stock selection model proposed in this paper has a significant advantage over the benchmark model A1 (considering only financial factors) and the benchmark model A2 (considering only predictive factors). This paper provides empirical experience and model design guidance for using machine learning for stock selection.

Data Availability

The data set can be accessed upon request to the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Shield Tunneling Parameters Matching Based on Support Vector Machine and Improved Particle Swarm Optimization

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Of late, emerging algorithms such as machine learning have been increasingly used in shield tunneling construction management and control. This research article proposes a shield tunneling parameter matching model based on a support vector machine (SVM) and an improved particle swarm algorithm (PSO) to enhance the accuracy and reliability of shield tunneling parameter selection. First, the optimization performance of the algorithm is augmented by adjusting particle diversity. Simulation-based experiments are conducted to test the performance of the improved algorithm. The experimental results indicate that the improved algorithm has better accuracy. Meanwhile, the particle diversity adjustment strategy is given. Then, the SVM model to express the relationship between shield tunneling parameters and ground settlement is established and trained. Based on the obtained SVM model, the improved PSO is used to optimize the tunneling parameters. The results show that the shield tunneling parameter matching model based on SVM and improved PSO can obtain more accurate shield tunneling parameters and provides a more precise reference for selecting shield tunneling parameters.

1. Introduction

With the advancement of civil construction technology, large-scale projects such as tunnels have an increasing impact on the development of the large, medium, and small cities and have made extraordinary contributions to urban economic development. However, soil loss at the tunnel entrance, soil instability at the driving face, and subsidence of the shield are common problems in shield tunneling construction. Therefore, the selection of reasonable shield tunneling parameters plays a decisive role in the smooth progress of the project. The numerous factors involved in the shield tunneling process introduce many inconveniences to selecting shield tunneling parameters. Subsequently, the shield tunneling parameters are needed to optimize the system.

Recently, machine learning algorithms are adopted in several fields such as healthcare, business, agriculture, and social media [1–4]. In the Industry 4.0 era, the digital world has a huge amount of data such as cyber security data, mobile data, business data, healthcare data, and social media data. The knowledge of artificial intelligence (AI) and machine learning (ML) plays a key role to analyze these data for the design and development of smart and automated application. Recently, several machine learning algorithms are widely used in the field of civil engineering [5–14]. These approaches yield several prospects for the optimization of shield tunneling parameters. In addition, the works which are related to settlement prediction [15–17] using machine learning algorithms are proposed. Existing machine learning-based approaches for the optimization of shield tunneling parameters face several challenges.

The existing machine learning approaches which are based on shield tunneling parameter matching use neural networks [18], K-means [19], correlation-based algorithms [20], and Bayesian networks [21]. These algorithms are failed to improve the accuracy and choose the optimal shield tunneling parameters. To obtain shield tunneling parameters more quickly and accurately, the paper enhances the PSO algorithm optimization performance by improving the particle diversity. A specific strategy is proposed based on the simulation results of six classical functions. Combining

60 monitoring data points from Shanghai tunnel engineering, SVM is adopted to establish the relationship model between the surface subsidence and shield tunneling parameters. Then, based on the obtained SVM model, the improved PSO is applied to optimize the tunneling parameters.

The remaining section of the paper is structured as follows: Section 2 discusses about the state-of-the-art works related to shield tunneling parameter matching. The proposed works such as SVM-based shield tunneling parameter matching and PSO-based algorithm to enhance the accuracy and reliability of shield tunneling parameter selection are presented in Section 3. The performance verification of the PSO-based approach is briefed in Section 4. Section 5 details about shield tunneling parameter matching model based on SVM and improved PSO. An extensive case study which is pertaining to the shield tunneling parameter matching approach is elaborated in Section 6. Section 7 explained about discussion and conclusion which is associated with this research work.

2. Literature Review

Within the context of the rapid development of information technology, researchers have improved machine learning algorithms to varying degrees and gradually applied them in several fields [1–4]. Of late, intelligent algorithms are gradually being widely used in the field of civil engineering [5–8], providing an opportunity for the optimization of shield tunneling parameters. As one of the main tunnel construction methods [9–12], the shield method is a complex mechanical process of undisturbed soil damage and reshaping. Since the excavated soil is subjected to shear and extrusion of the cutter head and grouting pressure of shield tail soil, different degrees of settlement and deformation are inevitably caused. At the same time, Shanghai, Hangzhou, Wenzhou, and other coastal cities in China are primarily in soft soil areas with poor antideformation ability. The settlement has a significant impact on tunnel construction to varying degrees, causing heavy economic losses and threatening human life safety [13, 14]. Therefore, the shield construction settlement has become the main problem endangering the health of subway and highway tunnels.

In recent years, the major geotechnical problem of ground subsidence caused by shield construction has attracted the attention of many researchers. Chen et al. [15] combined actual engineering data to build a model. Comparing six machine learning algorithms with traditional multiple linear regression methods, this article discussed the potential and advantages of machine learning algorithms in settlement prediction. Scott et al. [16] optimized and enhanced the soil compressibility prediction model through the SVM algorithm. This work effectively tested the correlation performance between the compressibility index and the soil index characteristics in the settlement calculation.

Hu et al. [17] proposed an extended machine learning framework based on actual data to prove that the PSO-SVR method has the highest accuracy among the three proposed prediction algorithms. To significantly reduce the surface subsidence, the researcher has studied the shield tunneling parameters related to the surface subsidence to improve the tunnel construction level and protect human life safety.

Jing and Gang [18] established a neural network model between shield tunneling parameters and ground settlement and then optimized shield tunneling parameters through a genetic algorithm. Min and Jie [19] proposed the shield tunneling parameter analogy setting method (SAPAS). The combination of the K-means clustering algorithm and the empirical formula setting method improved the practical application effect of the empirical formula.

Tian and Ma [20] tried to use a multidimensional correlation algorithm to optimize the shield tunneling technology and established a parameter correlation model through the Apriori algorithm. Zeng et al. [21] proposed a parameter optimization method based on DBN and applied it to the tunnel project in Wuhan, China. In addition, Bo et al. [22] obtained the best tunneling parameters by utilizing onsite monitoring. These studies, however, have limitations in adjusting the neural network grid weight coefficient, which causes the model to fall into the local optimal. K-means clustering algorithm can only get the local optimal in the iteration, and Apriori algorithm I/O load is large, which will produce too many candidate-project sets and other problems.

3. Methodology

3.1. Particle Swarm Algorithm (PSO). PSO is a stochastic optimization algorithm proposed by Kennedy and Eberhart [23] to simulate biological activities in nature. As a branch of evolutionary computing, PSO has been applied to solve various engineering optimization problems. PSO is different from the genetic algorithm (GA) since GA uses bio-evolution mechanisms such as crossover and mutation operations. But PSO has no such operations. They follow the optimal particle to replace, and the PSO has fewer parameters and is easier to implement.

PSO algorithm mainly relies on two extreme values to update the speed and position. One is the overall optimal solution of all particles, called the global optimal solution $p_g = [g_1, g_2, \ldots g_n]$. The other is the optimal solution of the particle itself in the entire iterative history, called the individual optimal solution $p_i = [p_{i1}, p_{i2}, \ldots p_{\mathrm{in}}]$ where $i = 1, 2, \ldots, M$. The ith particle is denoted by $x_i = [x_{i1}, x_{i2}, \ldots x_{in}]$. The velocity of the ith particle is $v_i = [v_{i1}, v_{i2}, \ldots v_{in}]$.

The iterative formulas are mentioned as follows: the ith particle is expressed as

$$v_{i\,d} = \omega \times v_{i\,d} + c_1\gamma_1\left(p_{i\,d} - x_{i\,d}\right) + c_2\gamma_2\left(p_{g\,d} - x_{g\,d}\right), \quad (1)$$

$$x_{i\,d} = x_{i\,d} + v_{i\,d}, \quad (2)$$

where $p_{i\,d}$ is the individual optimal solution, $p_{g\,d}$ is the global optimal solution, ω is the inertia weight, c_1, c_2 are learning factors, and γ_1, γ_2 are random numbers in the range [0, 1].

To improve the performance of PSO, the inertia weight is adjusted according to the following formula [24]:

$$\omega_t = (\omega_{\max} - \omega_{\min} - \mathrm{d}_1)e^{1/\left[1+\left[\mathrm{d}_2 t/t_{\max}\right]\right]}, \quad (3)$$

where d_1 and d_2 are control factors, the purpose is to control ω between $\omega_{\max}$ and $\omega_{\min}$, $d_1 = 0.2$, $d_2 = 0.7$, $\omega_{\max} - \omega_{\min}$ takes 0.5, and $t_{\max}$ is the maximum number of iterations.

This article further mediates the diversity of particles in PSO to improve the performance of PSO. In each iteration, particles are eliminated according to the proportion of 1/2, 1/3, 1/4, 1/5, and 1/6 to analyze the performance changes of particles, and specific improvement strategies are proposed based on the analysis results.

3.2. Support Vector Machine (SVM). SVM is a supervised machine learning method that can be used for classification and regression problems [25]. The optimal decision functions are constructed by mapping input variables to a high-dimensional linear space based on the principle of structural risk minimization. The appropriate kernel function is helpful to reduce the increase of computational complexity caused by the mapping from low-dimensional space to high-dimensional space. The optimal solution is obtained by sample training. The regression function for SVM is as follows:

$$f(x) = u \times \varphi(x) + b, \quad (4)$$

where u is the weight vector, $\varphi(x)$ is the mapping function, and b is the bias term.

The goal of optimization is

$$\min_{w,b} \frac{1}{2}\omega^2, \quad (5)$$

where points located within the boundary should satisfy $|y_i - (\omega x_i + b)| \le \varepsilon$.

The introduction of nonnegative Lagrange multipliers α_j, α_j^*, η_j, η_j^* further transforms the problem into the following equation:

$$\begin{aligned}\mathscr{L}(\omega, b, \xi, \xi^*, \alpha, \alpha^*, \mu, \mu^*) = {} & \frac{1}{2}\omega^2 + C\sum_{i=1}^{N}(\xi_i + \xi_i^*) - \sum_{i=1}^{N}\mu_i\xi_i - \sum_{i=1}^{N}\mu_i^*\xi_i^* \\ & + \sum_{i=1}^{N}\alpha_i[f(x_i)i - y_i - \epsilon - \xi_i] \\ & + \sum_{i=1}^{N}\alpha_i^*[f(x_i)i - y_i - \epsilon - \xi_i^*],\end{aligned} \quad (6)$$

where C is the penalty factor and ξ_i and ξ_i^* are relaxation factors.

The equivalent duality problem is obtained as follows:

$$\begin{aligned}& \max_{\alpha,\alpha^*} \sum_{i=1}^{N}\left[y_i(\alpha_i^* - \alpha_i) - \int(\alpha_i^* + \alpha)\right] - \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\left[(\alpha_i^* - \alpha_i)(x_i)^T(x_j)(\alpha_j^* - \alpha_j)\right], \\ & \text{s.t.} \quad \sum_{i=1}^{N}(\alpha_i^* - \alpha_i) = 0, \quad 0 \le \alpha_i,\ \alpha_i^* \le C.\end{aligned} \quad (7)$$

Restrictions are as follows:

$$\begin{cases} \alpha_i\alpha_i^* = 0, \quad \xi_i\xi_i^* = 0, \\ (C - \alpha_i)\xi_i = 0, \quad (C - \alpha_i^*)\xi_i^* = 0, \\ \alpha_i\left[f(x) - y - \int -\xi_i\right] = 0, \\ \alpha_i^*\left[y_i - f(x) - \int -\xi_i^*\right] = 0. \end{cases} \quad (8)$$

The bias term b is solved by the Caro required-Kuhn–Tucker condition and is presented as follows:

$$b = y^{(j)} - \sum_{i=1}^{n-k}(\alpha_i^* - \alpha_j)K(x^{(i)}, x^{(j)}) \pm \varepsilon. \quad (9)$$

The final SVM regression prediction model by using quadratic programming yields

$$f(\mathrm{X}) = \sum_{j=1}^{n-k}(\alpha_j^* - \alpha_j)K(x^{(j)}, x) + \overline{b}, \quad (10)$$

where $K(x^{(j)}, x)$ is the kernel function of the SVM.

The kernel functions commonly used in SVM are linear kernel function, polynomial kernel function, radial basis kernel function (RBF), and sigmoid kernel function. RBF kernel function has better convergence properties and is used in significant engineering prediction algorithms. Therefore, RBF is used as the kernel function for SVM models in the paper [26].

4. Improvement and Performance Verification of PSO

4.1. Improvement Method. In PSO, particles get different feasible solutions due to particles flying at different positions. That is, the diversity of viable solutions is called population diversity. Population diversity, also known as extensiveness and uniformity in PSO, is an important measure to evaluate the ability of PSO to search for feasible solutions. Therefore, to improve the population diversity, the paper explores the adjustment strategy of particle diversity by eliminating particles in the ratio of 1/2, 1/3, 1/4, 1/5, and 1/6 each iteration.

The specific experimental improvement strategy of this work is that the particles with smaller fitness values are eliminated in the ratio of 1/2, 1/3, 1/4, 1/5, and 1/6 according to their fitness values. Furthermore, the eliminated particles are generated by initialization. The individual optimal solutions and the global optimal solution are finally updated.

4.2. Validation of the Proposed Improved Algorithm. Experimental simulation analysis based on six benchmark functions is carried out to determine at what ratio the optimal value can be obtained. Table 1 shows the six benchmark functions.

The particle population size is 50, and the number of iterations is 200. The algorithm runs independently 15 times under each elimination ratio. The final results are shown in Tables 2–4.

Tables 1–3 show the optimal results obtained by the PSO with different elimination ratios. The minimum and average are visualized in Figures 1 and 2.

From the curves in Figures 1 and 2, F_1, F_2, and F_4 have higher searchability when the elimination ratio is 1/2. F_3, F_5, and F_6 are relatively close to each other regarding their searchability at each elimination ratio. The difference between each average value of the three benchmark functions F_3, F_5, and F_6 is tiny at each elimination ratio, indicating that the improved PSO has less influence on the stability. When the elimination ratio of F_2 and F_4 is 1/6, the average value is quite different from other elimination ratios. Moreover, it can be seen from the figure that there is a noticeable difference in the average value of F_2 under different elimination ratios, indicating the improved PSO algorithm has a significant impact on the stability of F_2. Except that the proportion is 1/6, the average value difference of F_4 under each elimination proportion is slight and significantly lower than other functions. This indicates that its stability is less affected by the improved PSO algorithm, and the optimization effect of the algorithm is better than other benchmark functions. According to the above analysis, it is clear from the figure that the elimination proportion of the three indicators in different functions is different, and the elimination proportion is not fixed and stable. The optimal value of each function has its own corresponding elimination proportion.

The iterations of six classical functions are shown in Figures 3 to 8. From Figure 3, the algorithm's corresponding elimination ratio of 1/2 is significantly more substantial than the other elimination ratios in the search for superiority before the 60th iteration. Between the 80th and 100th iterations, the searchability of each elimination ratio gradually approaches and starts to enter the local search phase. After the 160th iteration, each elimination ratio slowly converges and shows a clear distinction.

From Figure 4, the elimination ratio of 1/2 in two hundred iterations has better searchability than that under other elimination ratios. Except for the elimination ratio of 1/2, the function is not stable in the other elimination ratios before 100 iterations. After iterations, it gradually enters the local search phase. The searchability of each elimination ratio also slowly becomes an obvious distinction with a large gap, and finally, the function finds the optimal value in the case of an elimination ratio of 1/2.

From Figure 5, the iteration curve declines precipitously in the early stages and enters the local search phase more quickly. Before the 80th iteration, the function had the weakest search ability at an elimination ratio of 1/2. Since the 80th iteration, the searchability at the elimination ratio of 1/2 gradually increases and finally coincides with the iteration curve at the elimination ratio of 1/3. The elimination ratio that makes the function find the optimal value is 1/4. The function characteristics are similar to F_2.

From Figure 6, the iteration curve is clearly different from the other function curves. The function iteration curve as a whole decreases in a stepwise manner. At the same time, it can also be seen that the searchability at the elimination ratio of 1/4 is inferior before 50 iterations. After 50 iterations, its searchability shows a cliff-like growth. But after increasing to a certain level, there is no significant change between 60 and 160 iterations. Although it is further enhanced after the 160th iteration, it is still weaker than other elimination ratios in the end. As the elimination ratio is 1/2 for finding the optimal value, the function's ability to find the optimal value presents the characteristics of first being decisive, then weak, and then powerful. The algorithm gradually enters the convergence stage after 100 iterations and converges at the earliest when the elimination ratio is 1/6.

It can be seen from Figure 7 that the 1/4 elimination ratio has a significant advantage over other elimination ratios before the 70th iteration. In contrast, the functions under other elimination ratios show instability, weaker merit-seeking ability, and smaller gaps. At 80 iterations, the process gradually enters the local search phase under each elimination ratio. The iteration curve begins to converge as the searchability from different elimination ratios gradually stabilizes. The 1/4 elimination ratio that shows an absolute advantage in the first period gradually becomes inferior and finally overlaps with the 1/6 elimination ratio curve. While the 1/5 elimination ratio is inadequate in the first period, it shows a significant increase. This elimination ratio finally obtains the optimal value.

In Figure 8, the algorithm converges late, gradually converges after 120 iterations in each elimination ratio. The algorithm with an elimination ratio of 1/5 converges after 160 iterations. Before the 70th iteration, the elimination proportions did not show their respective advantages. In subsequent iterations, the searchability of the algorithm with an elimination ratio of 1/3 gradually increased and finally found the optimal value. The figure also shows that the merit-seeking ability is chronically inferior throughout the 200 iterations at a 1/4 elimination ratio.

Based on the above result analysis, through the overall analysis of the six benchmark functions and the independent study of each function, the six benchmark functions obtain the optimal solution. However, it is also found that different functions have their own most appropriate elimination ratios, so the min (1/2,1/3,1/4,1/5, and 1/6) strategy is adopted to solve realistic problems. If the same optimal value is obtained under different elimination ratios, the smaller elimination ratio is taken to improve the optimal solution's efficiency.

Table 1: Six benchmark functions used in simulation experiments.

Number	Benchmark function	Range of search	Dimension
1	$F_1 = \sum_{i=1}^{n} x_i^2$	[−10, 10]	20
2	$F_2 = \sum_{i=1}^{n} \lvert x_i \rvert^{i+1}$	[−10, 10]	20
3	$F_3 = \sum_{i=1}^{n} \lvert x \rvert_i + \prod_{i=1}^{n} \lvert x_i \rvert$	[−10, 10]	20
4	$F_4 = \sum_{i=1}^{30} i x_i^4 + \text{Gauss}(0,1)$	[−1.28, 1.28]	30
5	$F_5 = \sum_{i=1}^{n} x_i \sin(x_i) + 0.1 x_i$	[−10, 10]	20
6	$F_6 = 1/4000 \sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n} \cos + 1 (x_i/\sqrt{i}\ )$	[−200, 200]	20

Table 2: Comparison of the minimum values of six benchmark functions.

Elimination ratio	F_1	F_2	F_3	F_4	F_5	F_6
1/2	$1.42E-01$	$1.16E-05$	2.539306	$1.45E-05$	$9.05E-01$	0.811097
1/3	$1.65E-01$	$7.76E-05$	2.516099	0.000261	2.1564692	0.581494
1/4	$1.80E-01$	$4.28E-05$	2.187291	0.000151	1.5659153	0.866969
1/5	$2.10E-01$	$4.44E-04$	2.882946	0.000355	0.6863804	0.69168
1/6	0.235694	$1.91E-03$	3.386878	0.00051	1.5755379	0.78372

Table 3: Comparison of the average values of six benchmark functions.

Elimination ratio	F_1	F_2	F_3	F_4	F_5	F_6
1/2	0.802178	$1.85E+00$	$4.79E+00$	0.002589	3.6622543	1.051938
1/3	$9.90E-01$	$2.24E-01$	4.552009	0.003068	3.7624239	0.969001
1/4	$6.23E-01$	$7.09E-01$	4.647805	0.003354	4.3874189	0.982548
1/5	$6.71E-01$	$2.54E-01$	5.220595	0.004902	3.8896712	1.000483
1/6	$7.60E-01$	$1.67E+00$	5.10187	0.224481	4.0006234	1.018506

Table 4: Comparison of the RMSE values of six benchmark functions.

Elimination ratio	F_1	F_2	F_3	F_4	F_5	F_6
1/2	1.2287	$5.02E+00$	$6.14E+00$	0.004	4.9809	1.2941
1/3	$1.63E+00$	$8.97E-01$	5.9538	0.0049	4.8831	1.2038
1/4	$8.50E-01$	$2.68E+00$	6.0151	0.0068	5.81	1.2076
1/5	$9.27E-01$	$6.11E-01$	6.6692	0.0087	5.2275	1.2366
1/6	$1.20E+00$	$4.67E+00$	6.3881	0.9618	5.3412	1.2561

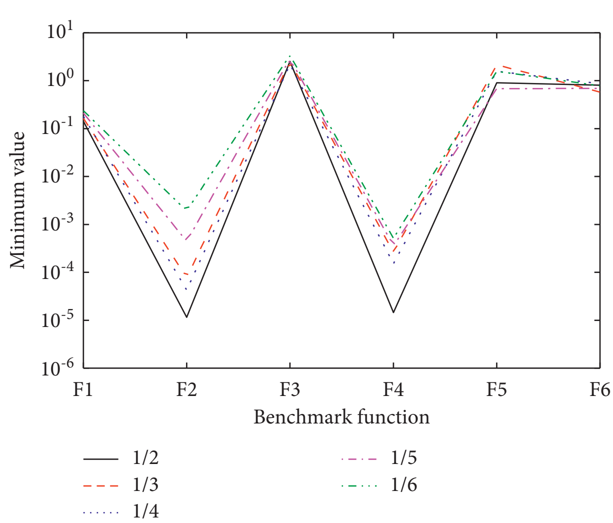

Figure 1: Six benchmark functions minimum value trend.

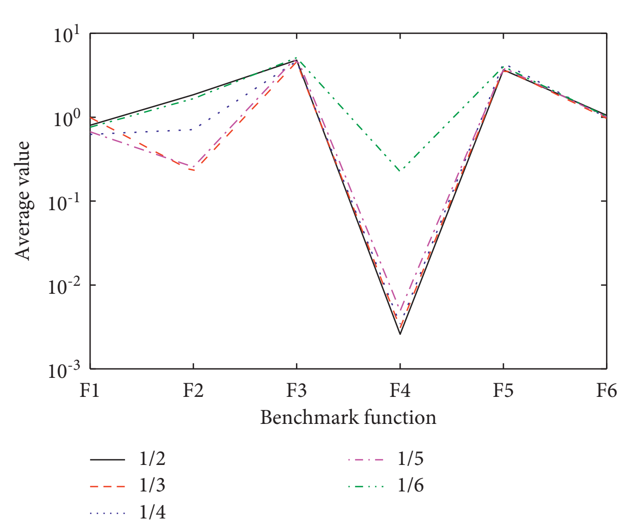

Figure 2: Six benchmark functions average value trend.

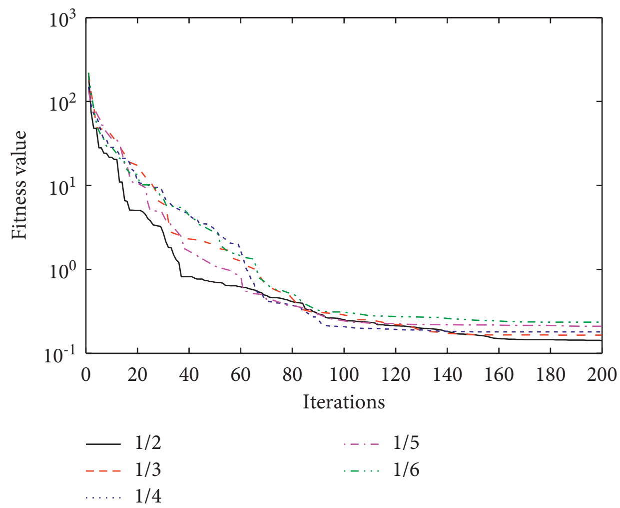

Figure 3: F_1 function iteration trend comparison analysis chart.

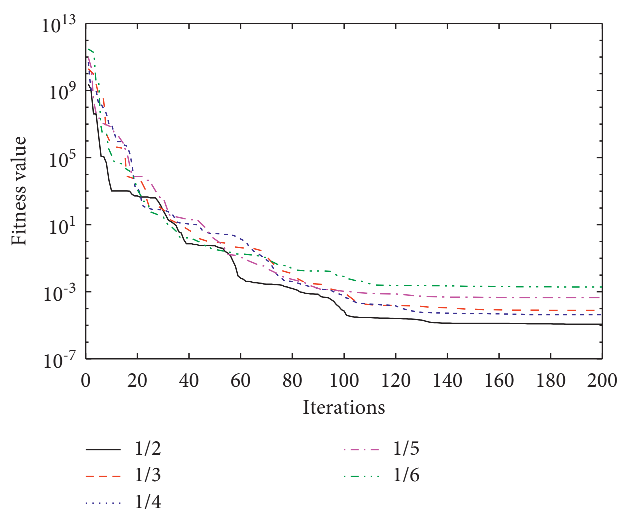

Figure 4: F_2 function iteration trend comparison analysis chart.

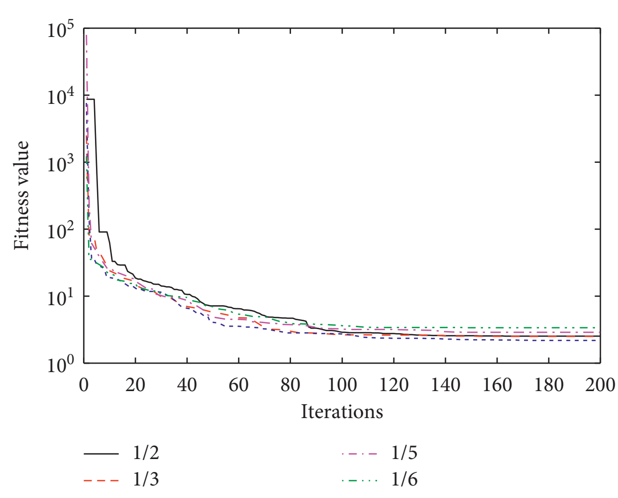

Figure 5: F_3 function iteration trend comparison analysis chart.

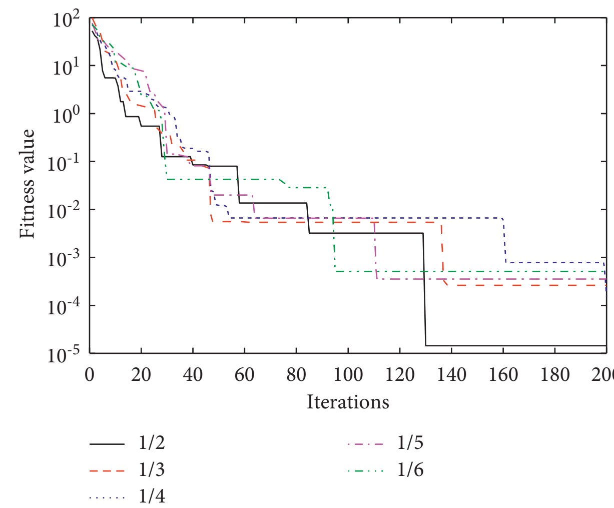

Figure 6: F_4 function iteration trend comparison analysis chart.

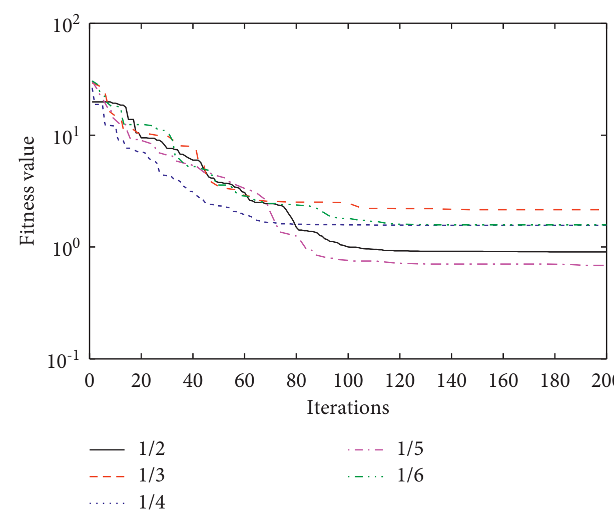

Figure 7: F_5 function iteration trend comparison analysis chart.

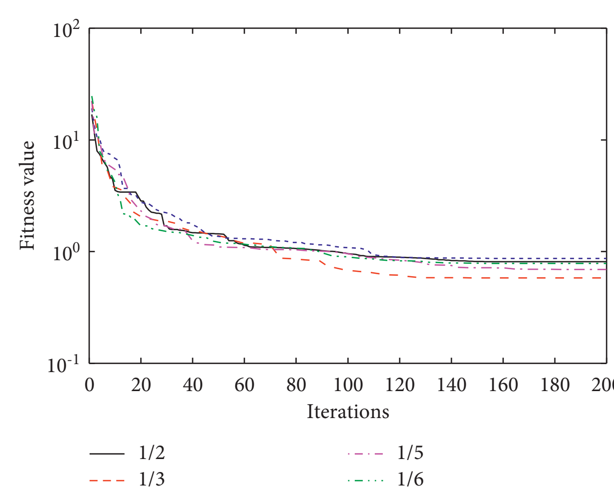

Figure 8: F_6 function iteration trend comparison analysis chart.

5. Shield Tunneling Parameter Matching Model Based on SVM and Improved PSO

5.1. Determination of Shield Tunneling Parameters. According to scholars' studies on tunneling parameters [27–32], the following parameters are the main ones affecting shield tunneling construction.

5.1.1. Soil Lateral Pressure Coefficient. The soil lateral pressure coefficient affects the soil state. The soil lateral pressure coefficient needs to be dynamically adjusted to keep the front soil in a state of passive Earth pressure. It is influenced by the surface conditions ahead and above the excavation surface. When the surface settlement is large, the soil lateral pressure coefficient needs to be increased. However, the soil lateral pressure coefficient needs to be reduced while the surface uplift is considerable.

5.1.2. Advancing Speed. The shield advancement speed influences the soil settlement in front of the shield blade. When the propulsion speed is high, the soil in front of the cutter head is easily squeezed by the soil in the soil tank and the panel, causing the surface to bulge. However, the soil in front of the cutter head will have surface settlement due to insufficient pressure at a low propulsion speed.

5.1.3. Grouting Filling Rate. Synchronous grouting is indispensable in the tunnel construction method to fill the construction gap caused by the shield in real time. Because the slurry enters the surrounding soil, the building gap cannot be filled entirely. Whether the building gap is filled will also have a significant impact on the surface. Therefore, the grouting filling rate is closely related to the surface settlement.

5.1.4. Grouting Pressure. When the grouting pressure is too enormous, it will make the slurry flow too much into the surrounding soil, which will improve the grouting rate but not the filling rate of grouting and will have a counterproductive effect. On the contrary, when the grouting pressure is too small, it will not guarantee the slurry injection. The grouting pressure needs to meet a certain pressure to complete the construction gap generated by the shield construction. At the same time, the soil near the end of the shield is uplifted by the extrusion, leaving a certain amount for subsequent consolidation and settlement.

5.1.5. Stopping Time. The shield machine will stop tunneling due to many factors during construction. At this time, the stopping time will have an impact on the surface settlement. With the extension of stopping time, the surface settlement will increase significantly.

5.2. Model Establishment. In the shield tunneling parameter matching process, it is necessary to find a set of optimal parameters within the allowable range of parameters and, finally, achieve the minimum surface settlement. However, the relationship between each tunneling parameter is mutually constrained. Many tunneling parameters cannot be expressed in a simple functional relationship with each other. SVM has the unique advantage of reflecting the complex relationship between the parameters. Therefore, it can be used to establish the relationship model between shield tunneling parameters and surface settlement. Based on the actual engineering data samples, the SVM model is trained. And then, the shield tunneling parameters are optimized by the improved PSO. The specific steps are summarized as follows:

(1) Particle parameters initialization, setting population size, iteration number, learning factor in PSO, Initializing the velocity and position of the particles (shield tunneling parameters) in the PSO, setting the dimensionality and the range of particle positions according to the requirements of different problems, and calculating the particle fitness values.

(2) The particle velocity and position are updated according to equations (1) and (2), respectively. Equation (3) is used to calculate the Inertia weights. The updated particle fitness values are calculated, and the individual extremes and population extremes are updated.

(3) After the update is completed, the particle population is eliminated according to 1/2, 1/3, 1/4, 1/5, and 1/6 for particles with low fitness values. The eliminated particles are generated by re-initialization, and their fitness values are calculated. Individual extremes and population extremes for new particles are updated.

(4) Loop step 2, step 3 until the end of the iteration condition.

(5) The reciprocal of the immense fitness value is used as the final settlement optimization value. The obtained tunneling parameter values are used as a reference for final parameter adjustment in the later stage.

6. Case Study

6.1. Project Introduction. The Earth pressure balance shield machine, with a diameter of 14.27 m, is used for the Shanghai bund tunnel project. The tunnel's total length is 1098 m [33]. The project requires high environmental protection. There are many buildings and historical preservation buildings along the tunnel, which creates many difficulties for the construction and increases the technical difficulty. In terms of geological conditions, the location traversed by the shield machine has a sandy chalk layer and clayey chalk soil interspersed with a chalky clay layer, which is prone to collapse and sand flow during excavation. In the construction process, the minimum overburden thickness during shield advance is 8.52 m which belongs to shallow overburden shield construction. This project's shield diameter is 14.27 m, making it more difficult to control the infiltration prevention and shield axis of the cave door.

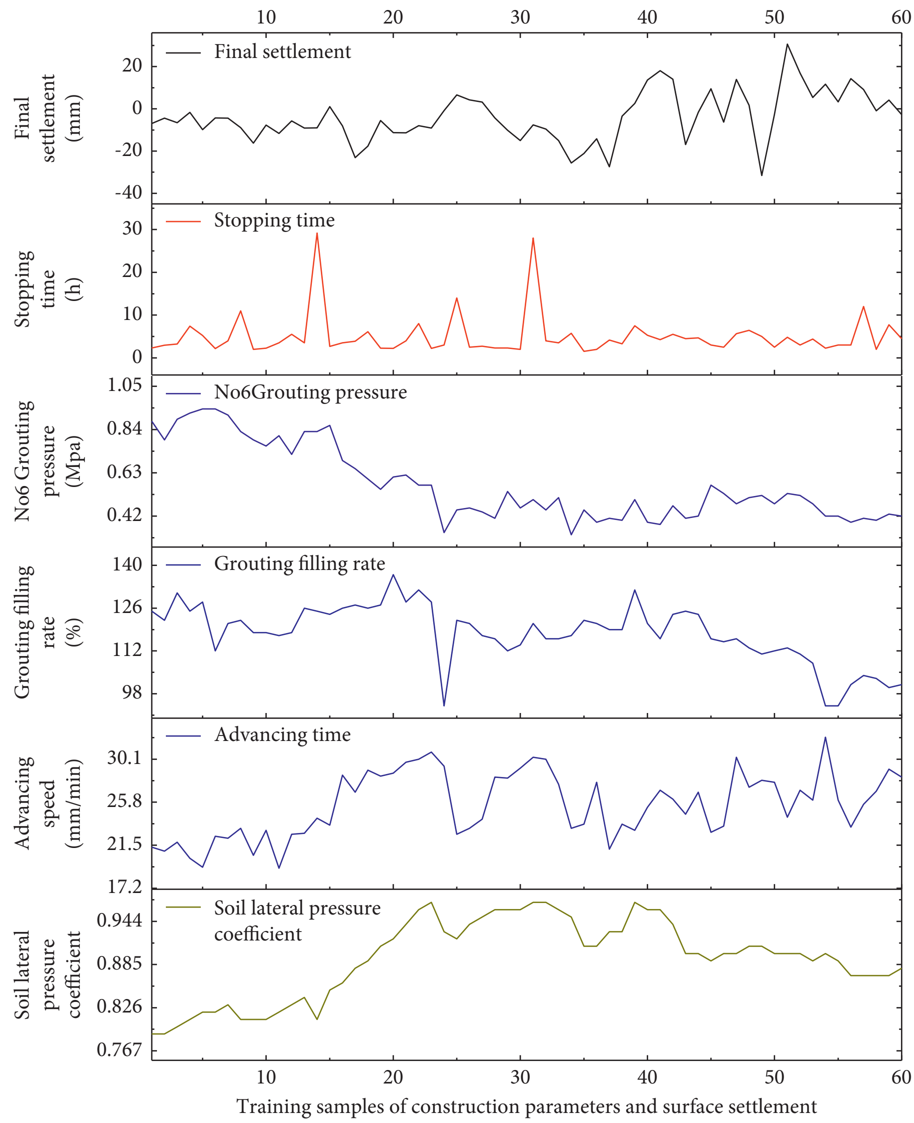

Figure 9: Training samples of construction parameters and surface settlement.

Because a shield machine with a large diameter is used, the usual experience of small diameter shield construction will not be applicable. The setting for the shield tunneling parameters will become more complex. It is necessary to take reasonable measures to set the critical shield tunneling parameters for maintaining the surrounding environment and reducing the impact on the surrounding environment and buildings along the route.

6.2. Optimization of Shield Tunneling Parameters. Sixty sets of monitoring points for the Shanghai Bund Tunnel Project are shown in Figure 9. These data are used to train the SVM model. Collection of real-time datasets in this machine learning task is challenging. So, we have chosen suitable machine learning algorithms which work better even in a small dataset. Support vector machines work better even in small samples [34, 35]. The parameters c and g in SVM were determined to be 18.5 and 2.1, respectively. It can be seen from Figure 10 that the training sample is consistent with the training output. The total error RMSE of the fitting system is 0.0844, indicating that there is good fitting. Combined with the test sample data in Table 5, the difference between the predicted and actual values is 11.8178% below 15%, proving that the model's prediction accuracy is based on SVM for the relationship between shield tunneling parameters and surface settlement is better.

The parameter value in PSO is set: population size is 50, the maximum number of iterations is 200, and the dimension is 5. The range settings for x_1, x_2, x_3, x_4, and x_5, which represent the soil lateral pressure coefficient, advancing speed, grouting filling rate, No6 grouting pressure, and stopping time, are [0, 2], [0, 50], [100, 200], [0, 1], and [0, 20], respectively. Optimization was conducted several times under each elimination ratio (1/2, 1/3, 1/4, 1/5, and 1/6) to obtain the minimum settlement value and corresponding optimal parameter. The fitness values were calculated based on the trained SVM model. Combining Table 6 with Figure 11, we know that under all elimination ratios, the minimum predicted value is 0 at the elimination ratios of 1/3, 1/4, 1/5, and 1/6. Five optimal

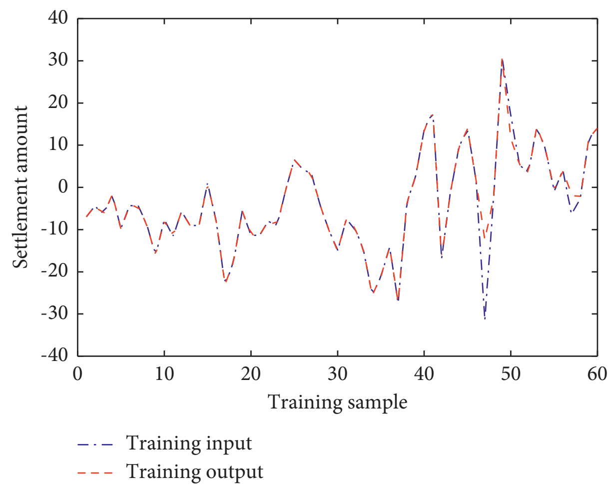

Figure 10: Training fitting diagram.

Table 5: Training samples of construction parameters and surface settlement.

Monitoring point	Soil lateral pressure coefficient	Advancing speed (mm/min)	Grouting filling rate (%)	No6 grouting pressure (MPa)	Stopping time (h)	Final settlement (mm)	Predicted value (mm)	MAPE (%)
B54–E	0.93	17.2	127	0.4	3	−10.3	−9.9699	11.8178
C27–E	0.85	26.2	99	0.4	5	11.01	12.8564	
B24–E	0.82	21.9	126	0.9	2.5	−8.63	−9.8693	
B40–E	0.98	28.8	126	0.4	2	−9.05	−10.2207	

Table 6: Prediction of settlement and optimization of parameter selection.

Monitoring point	Soil lateral pressure coefficient	Advancing speed (mm/min)	Grouting filling rate (%)	No6 grouting pressure (MPa)	Stopping time (h)	Final settlement (mm)
1/2	1.026913233	33.054732	110.2668425	0.511636618	12.20055	$6.075E-13$
1/3	0.853638066	14.598547	106.9142372	0.639073422	8.968524	0
1/4	1.020860055	35.226181	100	0.514805007	0	0
1/5	0.932789942	38.325932	128.4975161	0.401850619	4.791962	0
1/6	0.933834737	21.688509	120.3252482	1	9.179082	0

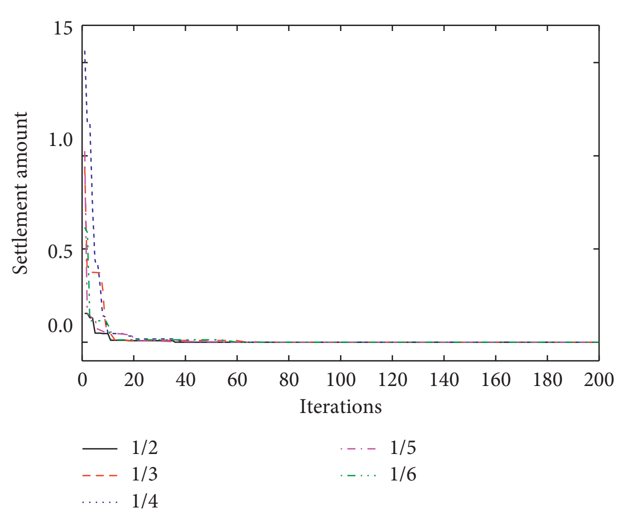

Figure 11: Comparative analysis of the predicted trend of subsidence under each elimination ratio.

Table 7: Prediction of settlement and optimization of parameter selection (Unimproved algorithm).

Monitoring point	Soil lateral pressure coefficient	Advancing speed (mm/min)	Grouting filling rate (%)	No6 grouting pressure (MPa)	Stopping time (h)	Final settlement (mm)
None	0.847265255	31.8067857	133.6892641	1	0	$7.10543E-15$
	0.878315843	35.13572442	104.2519731	0.732968534	2.181577284	$7.10543E-15$
	0.826208217	25.56947989	137.0125332	1	7.654577596	$2.13163E-14$
	0.863112949	26.58609905	127.2061708	0.390089676	20	$5.23194E-10$

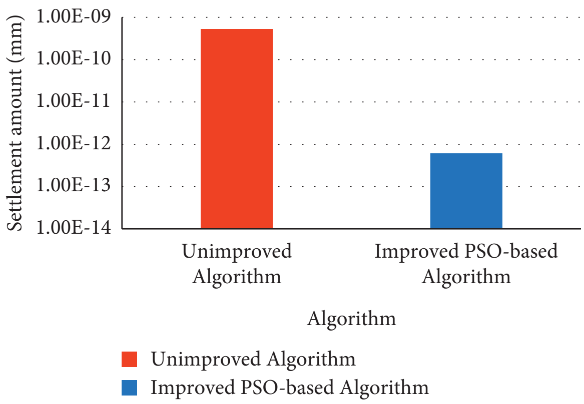

Figure 12: Comparative analysis of improved PSO-based algorithm and unimproved algorithm in terms of prediction of the settlement amount.

parameters are obtained as shown in Table 6, so 1/6 is taken as the elimination ratio for model prediction. Combining Tables 6 and 7, it can be seen that the improved algorithm with "elimination" can find smaller settlement values compared with the unimproved algorithm, which shows that the improved method proposed in this paper can find better settlement values and has certain research significance.

The main parameters considered in the model are soil lateral pressure coefficient, advancing speed, grouting filling rate, No6 grouting pressure, and stopping time. By combining SVM and PSO effectively, the model can obtain optimal parameter matching and the corresponding lowest settlement value. However, because the shield tunneling construction process is highly complex and involves many factors, the tunneling parameter value used in the final project needs to be further adjusted according to the optimized tunneling parameters. Therefore, the accuracy and reliability of the optimized tunneling parameters are essential. The method proposed in this study provides a more effective way for the selection of shield tunneling parameters.

In addition, an improved PSO-based algorithm is compared with an unimproved algorithm, and the settlement amount is recorded. The result is illustrated in Figure 12. It is clearly shown that an improved PSO-based algorithm has less settlement amount when compared to the unimproved algorithm.

7. Discussion and Conclusion

The paper first explores the strategy of adjusting particle diversity in PSO to improve the accuracy and reliability of shield tunneling parameter selection. Based on the analysis for simulation experiments, the particle diversity adjustment strategy is to take the optimal value of different elimination ratios. When the same optimal value is obtained under different elimination ratios, the smaller elimination ratio is used to improve the accuracy and efficiency of the optimal solution.

The SVM is applied to establish the nonlinear relationship between the shield tunneling parameter and the settlement value. Based on the Shanghai Bund Tunnel Project data, the SVM model is trained and tested. The result shows that the SVM model is a good fit and accurately describes the nonlinear relationship between each shield tunneling parameter and the final settlement. Finally, the improved PSO is used to optimize tunneling parameters. The improved PSO predicts that the amount of sedimentation will be close to zero. This is an ideal value. There are many other factors in practical engineering. The tunneling parameter value used in the final actual project needs to be further adjusted according to the optimized tunneling parameters. Therefore, the proposed match model in the paper can provide a better method for the selection of tunneling parameters in practical engineering.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Feature Extraction Technology-Guided Visual Communication Design for Folk Paper-Cutting

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Folk paper-cut art is one of the bright pearls, with a wide range of shapes and a long history, that serves as a model for modern visual communication design in China and encourages designers to think creatively. Integrating emotional elements into a design not only can elicit an emotional response from the viewer but also can make works created using traditional rational thinking more vivid, energetic, and touching. The main focus of this research is on the path and method of incorporating folk paper-cut emotion into visual communication design. The research status of various feature extraction methods and image recognition methods at home and abroad is examined in depth in this paper. For the recognition of distorted images that are not transformed by mathematics, some effective methods are proposed. They are used to recognize artistic images of paper-cut patterns because they can extract effective features that are not affected by translation, rotation, scale change, or small deformation. Experiments have shown that they have a positive impact. The use of folk paper-cut art in visual communication design not only improves the quality of design work but also generates new ideas for the transmission and development of other traditional Chinese cultures.

1. Introduction

As one of the traditional folk art forms in China, paper-cutting has been developing for more than 3,000 years. As one of the most distinctive art forms of folk culture, Chinese traditional paper-cut patterns, after historical baptism and deduction, have become an "image" cultural symbol with its unique artistic aesthetic concept and modeling means and are the visual carriers of Chinese traditional art, culture, and spirit [1]. Chinese modern experimental art and commercial culture design under the multicultural background have made a new interpretation of the "image" of folk paper-cut patterns through different contexts [2, 3].

The use of various forms of artistic expression, such as words, pictures, artistic modeling, and so on, to serve as information transmission and artistic promotion is referred to as visual communication design. The flatness, decoration, and cultural imagery of traditional paper-cut art are interpreted and designed through the visual communication design, which not only can give the visual communication design a strong expressive force but also can inherit and develop the paper-cut art [4–6]. The digital information age necessitates a mode of design thinking that is connected, integrated, systematic, and pluralistic, requiring us to recognize design problems from multiple perspectives and solve them using a holistic approach. Complementary perspectives and methods are one of the design methods that has piqued the author's interest and warrants further investigation [7]. Combining traditional folk paper-cutting with visual communication design and adding folk art to the foundation of modern design not only enriches the connotation of traditional culture but also adds an endless supply of new ideas to visual communication design.

With the blurring of traditional design boundaries and the visualization of emotional factors in design, the integration of emotion in visual communication design has become the decisive factor for the success or failure of design [8]. This paper combines wavelet analysis with other feature extraction methods. Wavelet analysis has the characteristics of multiresolution. If the features of images can be extracted based on wavelet multiresolution, the representation ability of feature vectors to images will be improved. By extracting

WM from the paper-cut pattern image, the multiscale features of the image can be obtained. The mean and standard deviation of different feature components are used to realize the feature selection of N-type patterns. Experiments show that this method can effectively remove noise interference and better identify paper-cut patterns with certain artistic exaggeration.

In this paper, the features and recognition methods of deformed images with nonstrict mathematical transformation are studied. The extracted features are not only geometrically invariant but also can recognize deformed images to some extent. In theory, the method of image recognition is broadened, and combined with the research of paper-cut art, it is applied to computer paper-cut, which lays a foundation for the realization of computer paper-cut.

2. Related Work

Although there were some new names for visual communication design more than ten years ago, it is now buried in the "visual age" and "visual culture." Literature [8] puts forward that visual communication design is a planned and effect-oriented design image generation and communication activity for people to achieve a certain purpose (such as information transmission, influence, promotion, and expression), that is, the design of the design image and its transmission mode. Literature [9–11] hold that visual communication design is a process in which designers transform ideas and concepts into visual symbols to convey information by visual symbols. Literature [12] holds that it includes the design of "visual communication design," graphic design, such as posters, photography, signs, fonts. Literature [13] holds that visual communication design refers to a design activity that uses modeling means and various visual media to convey information, mainly including the design and expression of visual information elements such as graphics, words, colors, images and aims to convey information accurately, quickly, and effectively. The design process mainly includes the generation of plans and ideas, translation and generation of visual images, and presentation and transmission of visual information. Literature [14] introduces the relationship between people and things in design and emphasizes how to grasp the design idea of starting from people's needs and returning to people when human beings enter the information age of audiovisual new sensibility from the age of reading and writing. Literature [15, 16] focus on the analysis of designers and audiences, discuss the differences between the psychological starting points of designers and audiences, and finally attribute the core concerns of visual design to the practicality of products and the emotional experience of audiences. Literature [17] has a more in-depth exposition on designer psychology, product experience, and experimental design of design psychology. Literature [18] reveals the general creative psychological activity law of art designers themselves in the creative process and guides and meets the psychological needs of consumers through design.

Template matching is the simplest method of image recognition, and it can be divided into two categories: rigid body shape matching and deformed template matching. Template matching is the process of comparing the template to the image to be recognized in order to find areas in the image that are the same or similar. Character recognition, face recognition, hand shape recognition, and other fields all use template recognition. Several finger outlines in the whole hand shape are extracted as templates in the literature [19], and the recognition rate is greatly improved by using the method of block matching and the function of direction angle. The Clifford convolution algorithm of template matching is used in literature [20] to improve the grid division of flow fields for a given flow field. Literature [21] proposes a fast template matching method that identifies the target by combining the central invariant moment with the template, aiming to overcome the drawbacks of large computation, rotation, and scale influence. The sample data from high-dimensional space were projected into one-dimensional space by literature [22] so that different samples were as far apart as possible, while similar samples were as close as possible. Literature [23] improved it by employing weighted or adaptive methods, resulting in a more accurate minimum distance method. Literature [24] investigated the graphic generation method for paper-cut patterns and used computer graphics technology to generate spline curves to construct paper-cut patterns, resulting in the creation of a computer paper-cut system based on patterns and the automation of the paper-cut system. Literature [25] is a breakthrough in the field of paper-cut pattern design, employing a genetic algorithm to generate a variety of paper-cut patterns in various styles.

3. Research Method

3.1. Convey the Emotional Integration of the Basic Elements of Folk Paper-Cutting in Visual Design. Folk paper-cut art, as a special form of artistic expression, has been loved by people in the process of its emergence and development, and working people pin their beautiful feelings on paper-cut. As a unique symbol, paper-cutting also has its unique use-value, conveying the faith of working people. Chinese traditional paper-cut art contains the aesthetic taste and modeling creation of working people. Working people pin their feelings on paper-cutting art and show their interest in life through different paper-cutting art forms. Visual communication design mainly analyzes and summarizes the images in paper-cut art and then displays them in the design works.

Traditional Chinese paper-cut art is primarily red with white accents, with simple red and white colors used to express paper-cut art. Paper-cut artistic modeling primarily expresses people's emotional experiences by combining reality and reality and incorporating images of everyday animals into paper-cut. Working people's lives are mostly represented by paper-cutting art. They can think creatively and express themselves exaggeratedly through various modeling patterns because they are not overly bound. This is similar to western artistic expression, and the works of art are romantic in nature. Direct graphical emotional expression and indirect graphical emotional expression are the two types of graphical emotional expression. The direct expression of graphic emotion is a realism built according to the original appearance of objective images, with a shape that is similar to the actual shape, reflecting true details and the typical essence of images. Indirect graphic forms are conceptual symbols created according to the prototype's concept and meaning, making it impossible for people to distinguish the original image and meaning. They are graphic forms with objective meaning derived from pure geometric concepts such as points, lines, planes, bodies, and their combinations or graphic forms with simple characteristics derived from them, and they are widely used in business, such as logo design.

Image motion is one of the most characteristic design factors, and it is also the fundamental difference from the traditional static visual communication design form. The way of movement can be divided into the movement of visual elements (images, characters, colors, lines, etc.) and the movement of design space areas (as shown in Figure 1).

For the movement with visual elements as the main body, it can generally be realized through image change, position change, and nature change. These methods draw lessons from the methods of visual communication design with printing as the carrier, but the difference is that in dynamic activities, more emphasis is placed on the process evolution and dynamic changes, rather than a single result. The visual elements can move in a two-dimensional plane or three-dimensional space.

Because there are so many different ways to express punctuality, different forms will have different emotional expressions. A larger point, for example, will give the impression of conciseness, simplicity, and lack of hierarchy. Small dots will be rich, gleaming, insignificant, and dispersed. There is a sense of detention and order. Dots are athletic, supple, and flawless. People will experience various emotions as a result of various combinations. The sum of point, line, and surface emotions creates modeling emotion. The incomplete shape gives people a sense of regret and sigh; complete shape gives people a sense of complete and complete emotional feeling. Virtual bodies give people a sense of emptiness and floating nothingness, while entities provide a real and credible sense of existence. People with a large shape experience a lot of depression, while those with a small shape experience a tight contraction. Geometry instills a sense of rigor in people, while freedom instills a sense of relaxation. Abstract modeling gives people a sense of science fiction transcendence and psychedelic mystery.

Decorative design is mainly for external image design of decorations, including external image and internal concept communication. Therefore, designers can deform the original patterns by exaggeration and pay attention to the use of paper-cut art concepts to enhance its cultural connotation to arouse consumers' consumption resonance. Therefore, in the decoration design, learn the exaggerated techniques of traditional paper-cutting art, update the design concept of visual communication, and improve the design level.

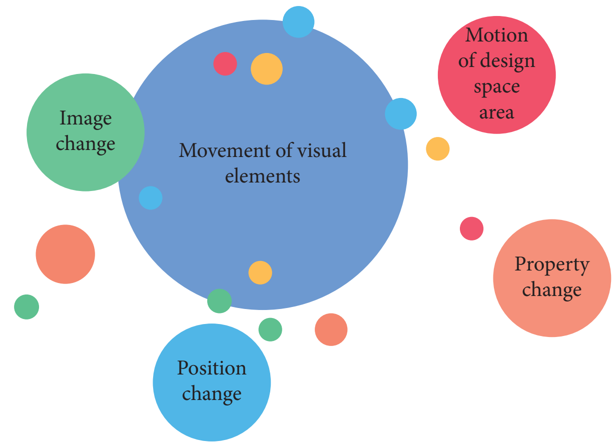

Figure 1: Analysis of motion mode of a dynamic image.

3.2. Research on Paper-Cut Pattern Recognition

3.2.1. Pattern Recognition Based on R-T and SVD. Paper-cut pattern pretreatment is an important link in pattern recognition and classification. The preprocessing of this paper includes background denoising, image graying, and binarization, as shown in Figure 2.

Compared with other crafts, paper-cutting materials and tools are the simplest, mainly composed of paper, scissors, carving knives, and so on. Because of the tools, paper-cutting has its own characteristics in artistic features. On the basis of its hollowed-out shape, there are two situations, that is, lines are connected or lines are broken. The paper-cutting has a simple and exaggerated aesthetic feeling. Simple modeling, clever and imaginative artistic conception, concise structure, and bright colors have become the important features of paper-cutting art.

The mathematician Radon studied the problem of finding the function along the integral value of a straight line or plane in two- and three-dimensional functions, which is called R-T (R-transformation) of Euler space. Nowadays, it has been widely used and played an important role in image recognition.

The radon transform of an N-dimensional function $f(x_1, x_2, \ldots, x_n)$ is defined as the integral value on the $n-1$-dimensional hyperplane. When $N = 2$, the radon transform of the function $f(x, y) \in L^2(D)$ on the plane refers to the integral of $f(x, y)$ along all possible straight lines, which is recorded as follows:

$$\begin{aligned} p(t,\theta) &= R(t,\theta)\{f(x,y)\} \\ &= \int\int_D f(x,y)\delta(t - x\cos\theta - y\sin\theta)\mathrm{d}x\mathrm{d}y, \end{aligned} \tag{1}$$

where $\theta \in [0, 2\pi]$, δ is the impact function, and D can be a circle or other plane area.

Let image $f(x, y)$ be $p(t, \theta)$ after radon transform, and continuous R-T definition is as follows:

$$R(\theta) = \int_{-\infty}^{\infty} p^2(t,\theta)\mathrm{d}t. \tag{2}$$

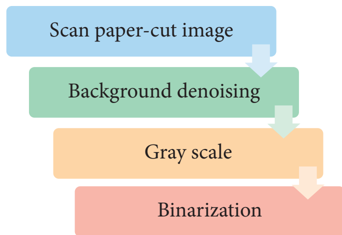

FIGURE 2: Paper-cut pattern.

That is, on the basis of radon transform, the integration of $p^2(t,\theta)$ along t can transform the two-dimensional information into one-dimensional.

Image scale change λ, R-T, there are

$$\int_{-\infty}^{\infty}\left(\frac{1}{\lambda}p(\lambda t,\theta)\right)^2 \mathrm{d}t \overset{\rho=\lambda t}{=} \frac{1}{\lambda^3}\int_{-\infty}^{\infty} p^2(p,\theta)\mathrm{d}\rho = \frac{1}{\lambda^3}R(\theta). \tag{3}$$

From the above properties, it can be known that the image after R-T is obviously invariant of translation. However, when the image is rotated, just like the radon transform, there will be a line shift phenomenon, but other things remain unchanged.

SVD (singular value decomposition) is an effective method to extract algebraic features of images. According to matrix theory, SVD is an important matrix decomposition method in linear algebra, and it has many excellent characteristics in describing the distribution characteristics of matrix data. In an image, any matrix can be decomposed into diagonal matrices by SVD.

The SVD theorem includes

$$\begin{aligned} AA^T u &= \lambda^2 u, \\ A^T A u &= \lambda^2 u. \end{aligned} \tag{4}$$

That is, it has the same singular value for A, A^T. Therefore, if the image matrix is transposed, the singular value feature will not change.

3.2.2. Pattern Recognition Algorithm Based on WM. Color is not only a composition element but also a dominant element, and it is also an important determinant of the emotion of design works. Only when you know the color can you use the right color to enhance the emotion of the design work. By skillfully using and controlling colors, you can strengthen your emotions in the direction you need.

The moment has been widely used in the field of image recognition, and its invariance of translation, rotation, and scaling can well represent the features of images. Paper-cut image has its unique characteristics, and its image is distorted and exaggerated. Paper-cut techniques can be divided into female cutting and male cutting, resulting in deformed patterns, which can lead to errors only by relying on intuitive features to identify. Most importantly, the image of paper-cut patterns is different from other images. Two similar patterns do not necessarily have strict mathematical transformation. They are the result of artistic exaggeration and deformation, and they are arbitrary.

In order to achieve the desired effect, follow the characteristics of WD (wavelength decomposition) to get the details of the pattern, and use the multiscale characteristics of WD to describe the changing characteristics of images on different scales, which is more suitable for image information processing.

Let $f(x,y)$ represent a continuous function, and the continuous standard moment of the image can be defined as follows:

$$m_{pq} = \iint x^p y^p f(x,y)\mathrm{d}x\mathrm{d}y. \tag{5}$$

By transforming the equation from rectangular coordinate system to polar coordinate system, the moment characteristic expression with rotation invariance can be obtained as follows:

$$F_{\mathrm{pq}} = \iint f(r,\theta)g_p(r)e^{jq\theta}r\mathrm{d}r\mathrm{d}\theta, \tag{6}$$

where $g_p(r)$ is the radial component of the transformation kernel and $e^{jq\theta}$ is the angular component of the transformation kernel. Order

$$S_q(r) = \int f(r,\theta)e^{jq\theta}\mathrm{d}\theta. \tag{7}$$

Further change the above formula into

$$F_{\mathrm{pq}} = \int S_q(r)g_p(r)\mathrm{d}r. \tag{8}$$

If $g_p(r)$ is a function of the local definition of the variable r, the difference between samples may be larger, and the noise will inevitably decrease so that the change areas of sample features are unlikely to overlap with each other, which is a key idea to extract invariant moments of appropriate order from images by using wavelet transform.

Here, the WM (wavelength moment) extracted by the above method is used as the feature vector of the paper-cut pattern. However, due to the high dimension of WM features extracted by different scale factors, selecting favorable features reasonably and effectively and reducing feature dimensions appropriately can eliminate redundancy, speed up operation, and improve classification efficiency.

There are w pattern classes to be distinguished, and each pattern class has one sample. Let the sample be s, where i is the i-th sample of pattern r and k is the k-th feature component of sample i; then the mean and standard deviation of the k th feature component of pattern r are as follows:

$$\begin{aligned} m_k^r &= \frac{1}{l}\sum_{k=1}^{n} X_k^r, \\ \delta_k^r &= \sqrt{\frac{1}{l}\sum_{k=1}^{n}\left(X_{ik}^r - X_k^r\right)}. \end{aligned} \tag{9}$$

For two kinds of samples, the larger the gap between the mean values of a certain one-dimensional feature component and the smaller the sum of variance, the better the separability of the component.

If China's modern visual art is to establish its own cultural identity in the international cultural exchange world, it must research and utilize its own country's traditional cultural resources while innovating and developing modern visual art and design. The significance of this issue has grown in recent years. As a result, the significance of this paper is to innovate the "image" of traditional folk paper-cut patterns using western theories, to inherit and express Chinese traditional culture in the most appropriate form, and to build Chinese contemporary visual art and design with local cultural connotation.

4. Results Analysis and Discussion

4.1. Experimental Results and Analysis of R-T and SVD Recognition. The artistic conception beauty of design works is the highest level of spiritual function and the highest requirement for visual design, which means that the environment has a specific atmosphere or profound artistic conception. The space mentioned here also has two meanings. The first one is the real space, that is, the real three-dimensional design and expression space. The second is the picture space, that is, the space of false two-dimensional plane design and expression. The visual communication design is more focused on the latter's space design.

The use of corresponding association to change unfamiliar to familiar, and to change the cognition, understanding, feeling, and experience of the other object to the theme to be expressed, is primarily used in the theme expression of visual communication design. The audience is more familiar with the other object than the theme to be expressed, making it easier for them to understand and accept it. People's imagination and creation can be used to enhance the theme's connotation. As a result, it is not advisable for China's modern visual art design to deliberately pursue national traditions in order to compensate for deficiencies or to westernize in order to accommodate international styles. Instead of sticking to certain appearances and styles, one of the best development directions is to learn from the expression of "image" in folk paper-cut patterns and create contemporary visual art with national cultural connotations.

R-T experiments are carried out on images with different geometric transformations of the same pattern, and the results are shown in Figure 3.

From this, the nature of R-T translation, scaling invariance, and rotation cycle motion can be seen clearly. Because the singular value of the matrix is independent of the position of rows and columns, the rotation variation can be eliminated according to this characteristic.

Design emotion and design thinking are the basic elements that any art category should possess. Emotion without proper thinking cannot constitute design, and thinking that cannot express emotion cannot be regarded as art either. In order to make visual design works have a profound artistic conception, from the creative point of view, it is necessary to see the situation and express feelings first and then express feelings, that is, entrust things to express feelings. From the perspective of appreciation, it means that the appreciator can be inspired, felt, edified, and even shocked by inspiration from the perceived spatial environment, which can arouse the resonance of thoughts and emotions, that is, feel the situation and feel the emotion suddenly.

The experimental results of noise resistance comparison between the two methods are shown in Figure 4. It can be seen that this algorithm is more robust than radon invariants and can well overcome the influence of noise.

The following shows that the algorithm in this paper is more effective in translation, rotation, scale invariance, and similar image recognition than the algorithm in reference [24]. The experimental results are shown in Figure 5.

The features obtained by using R-T and SVD are invariant, as shown in Figure 5, and the algorithm is simpler and more effective than radon moment invariants. R-T has a minor effect on the scale here, which is primarily due to some jaggies in the enlarged image. Visual communication design is based on artistic ideas and modeling characteristics, deconstructs folk paper-cut art expression skills again, and perfectly combines folk paper-cut with visual communication design, enriching the category of visual communication design. Visual communication design has evolved into a new form of personalized and traditional artistic expression in recent years.

The second group of experiments is feature extraction of similar images. Here, only some illustrations are listed to illustrate their singular value features, as shown in Figure 6.

It can be seen from Figure 6 that the invariant features constructed by radon are scattered, and the features in the same category differ greatly, so the method in reference [24] is not suitable for feature extraction of deformed images. The method of R-T and SVD is better.

Modern visual communication design is the reconstruction of graphics and images, and it is based on universal visual language to create a lot. Instead of sticking to the expression of objective images, the expression of ideas is usually carried out with the help of designers' subjective thinking mode, which will come from everyday life and all kinds of things.

In this paper, a large number of experiments have been carried out on seven kinds of patterns, which proves that this method can effectively extract invariant features. Due to the limitation of space, only four samples are listed for each of the following patterns, as shown in Figure 7.

From Figure 7, it can be seen that the characteristics of these seven modes are different, but they are relatively concentrated on the whole. In recognition training, those patterns that are too scattered can be removed, which is conducive to correct pattern classification. For patterns with complex deformation, there will be some cross-feature values.

Visual communication design should not only highly summarize the folk paper-cut art but also highly purify these artistic shapes, so as to find a concise and clear modeling image to embody in the visual communication design, thus

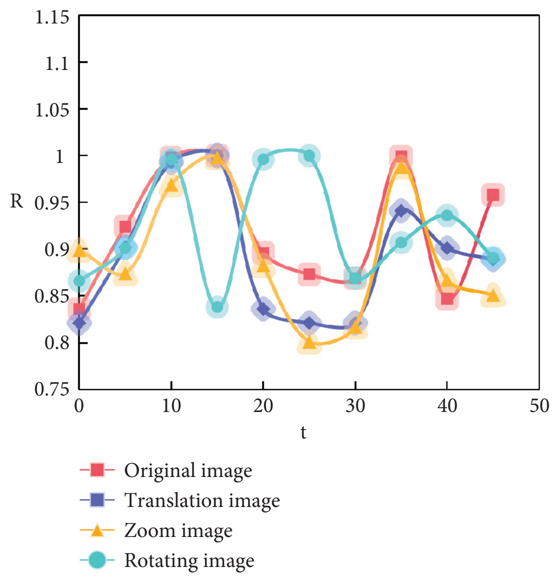

FIGURE 3: The results of geometric transformation and original graph R-T.

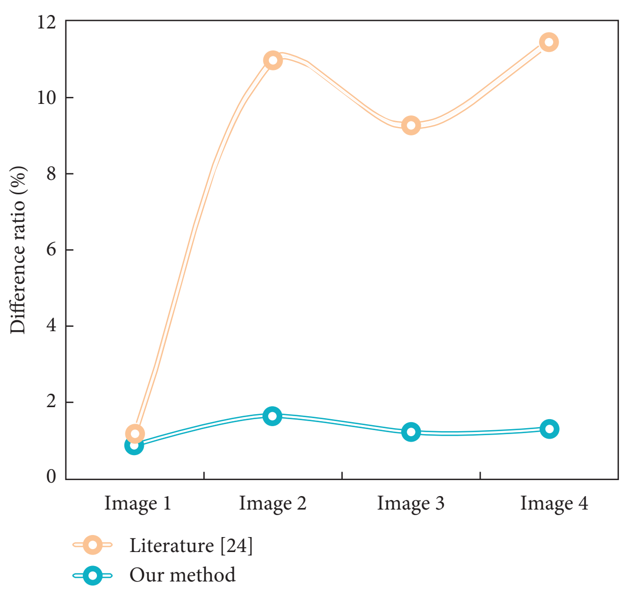

FIGURE 4: Comparison of noise resistance between two methods.

enhancing the artistic appeal. With the continuous development of science and technology, the performance field of visual communication design has also brought new changes, with more emphasis on the integration of traditional and modern elements.

4.2. Analysis of Pattern Recognition Results Based on WM. Visual communication design is not only the fullest beautification and decoration of artistic image but also the ideological expression of artistic creators. For example, the auspicious symbols in folk paper-cut art are applied to visual communication design, which shows the lofty idea of the happy life of the folk people and unique artistic skills. Visual communication design conveys realistic art and different kinds of artworks all present the public's thinking mode and aesthetic concept.

Sort each column from largest to smallest and set the threshold value to the average of the first three feature components. As the final feature vector, choose the feature component with a resolution greater than the threshold value. Despite the high resolution of some feature components, their feature values are small and have little impact on the Euclidean distance classifier. As a result, such feature vectors can be directly discarded to reduce redundancy and improve calculation speed. The identification result of WM is shown in Figure 8.

According to the above Figure 8, it can be seen that the WM method has a good recognition effect for different types of patterns. The high recognition rate of WM is mainly attributed to WM's grasp of details. The WM features extracted after image normalization are invariant to translation, scaling, and rotation of moment features. At the same time, the multiscale characteristics of WM features make WM invariants represent not only global features of images but also local features, so they can better represent the differences in image details and have a higher recognition rate when identifying similar objects.

The feature extraction method proposed in this paper is based on WD. Here, the feature extraction proposed in this paper is compared with other recognition methods, as shown in Figure 9.

According to Figure 9, it can be seen that among the above four feature extraction methods based on wavelet transform, WM has the highest recognition rate, mainly due to the multiscale characteristics of WM features, which makes WM invariants not only represent global features of images but also represent local features. However, its feature extraction process is cumbersome, and at the same time, it is complicated to select the extracted features.

The forms of folk paper-cutting collide with new energy and new technology in the development of modern design, absorbing the cultural characteristics of various styles and resulting in certain creations. It is reexhibited in a brand-new form through various expressions of visual communication design, resulting in folk art that not only meets the needs of the times but also retains its own distinctive characteristics. The paper-cut image is a very real modeling language with more prominent morphological features in traditional visual elements. Artists combine the ever-changing artistic images of folk paper-cutting with contemporary modeling languages and artistic forms to provide people with endless emotional experiences and a happy atmosphere. Each of us has a deep understanding of these symbolic languages and ideologies. After historical changes, people continue to love and recognize them, and they have become a popular artistic pursuit in the public's minds.

People process the inherent attributes of things, and with the symbolic connotation of art, folk paper-cutting uses a lot of decorative techniques of symbols, metaphors, and metonymies to convey emotions and conveys happy wishes. Modern designers use this expression to exert great creativity and imagination, expand the inherent space of design,

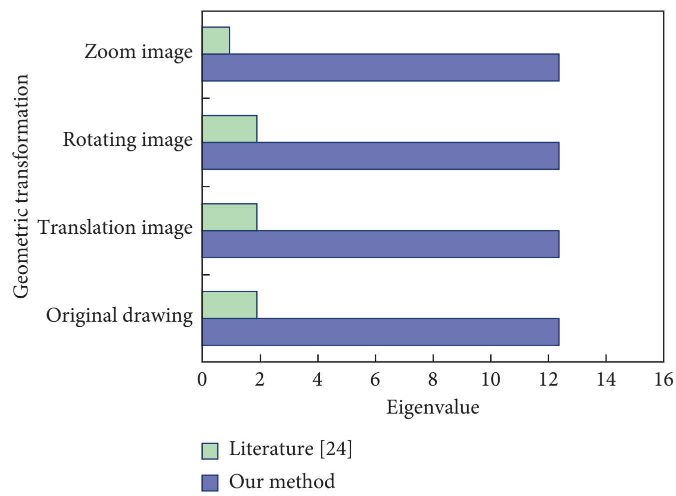

FIGURE 5: Comparative experiment of geometric transformation.

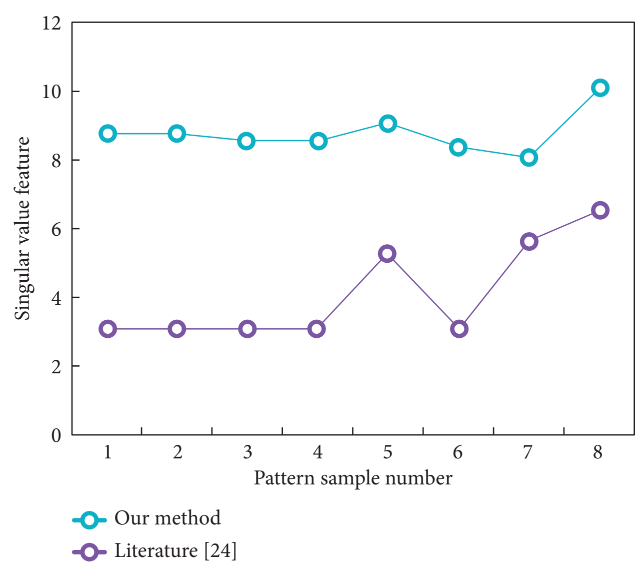

FIGURE 6: Contrast experiment of deformed patterns.

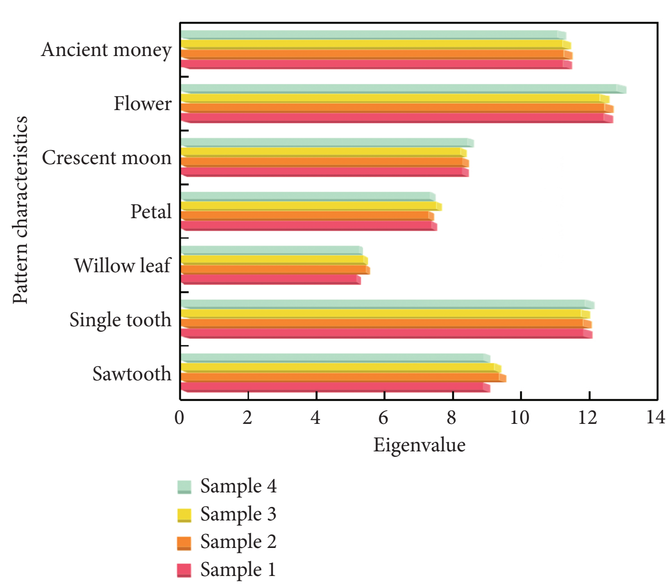

FIGURE 7: Pattern characteristics.

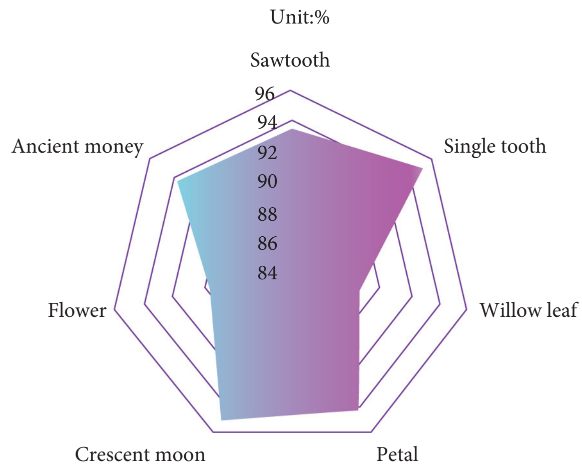

Figure 8: WM's recognition result.

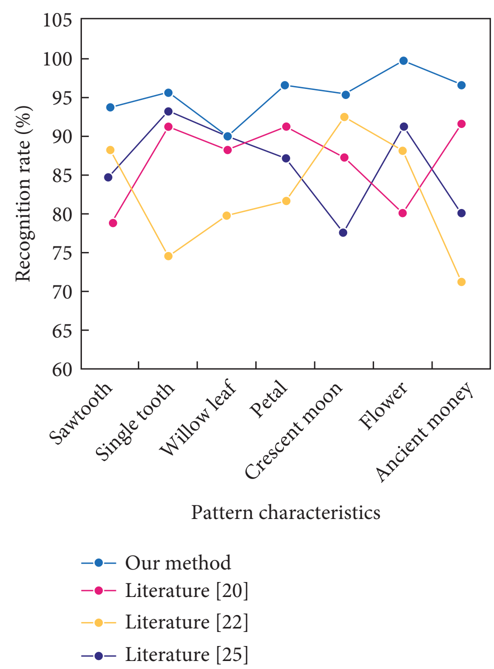

Figure 9: Comparison chart of identification of different algorithms.

create more valuable artistic works, and form the inherent artistic language of folk local design.

5. Conclusion

Chinese traditional paper-cut art modeling has become increasingly popular as modern society has progressed. In the design process of artworks, people always incorporate patterns in paper-cut art. Paper-cut art can provide materials for designers to innovate when incorporated into modern visual communication works. These works of art can pique people's interests and help them communicate their charm more effectively. It is the key link between Chinese culture and world art, and the folk forms it contains are exactly what modern visual communication seeks. Today, with the rapid advancement of science and technology, the folk paper-cut art will be presented to the world with a brand-new creative technique, and the entire aesthetic form will be developed and can be extended and inherited for a long time, in order to preserve the folk art more completely. This paper also focuses on the method of feature extraction. The structural features of the target are represented by the features extracted in this paper, which are not affected by translation, rotation, or scale transformations and have good robustness. Experiments have shown that these techniques are effective.

The next step will be to develop a paper-cutting-friendly image segmentation algorithm. Image segmentation will divide and identify a complete paper-cut image into individual patterns in several pattern libraries, allowing complex patterns to be recognized.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Structure Strength Dynamic Strain Measurement Acquisition System Based on Data Fusion

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Strain measurement technology plays an irreplaceable role in measuring the force change characteristics of mechanical components and monitoring important engineering structures. In structural health monitoring, dynamic stress and strain testing is the main way to determine its overall fatigue, and excessive stress will seriously affect the strength of the structure, causing the structure to deform or even break, which will affect the reliability of the experiment and the use of workpieces, so it is of great significance to carry out dynamic stress and strain tests on the structure. Resistance strain measurement technology is widely used in the civil engineering industry, but the principles of modern physics technology are unknown to many practitioners. Data fusion technology or information fusion technology is also called multisensor fusion technology. Using computer technology to automatically analyze and integrate the data processing process of the detection data from multiple sensors according to time sequence and certain criteria, it can complete the required decision-making and judgment.

1. Introduction

With the development of economy and technology and the progress of science and technology, more and more cars, airplanes, and ships are connected to people's daily life, and people have put forward higher requirements for their safety performance [1]. When the vehicle is running at various speeds and different road sections, the wheels are excited by the ground irregularly. This irregular random excitation causes irregular vibration of the body structure, that is, random vibration. In order to meet its safety requirements, it is an important way to conduct health monitoring to evaluate its structural safety performance. As a result, strain measurement technology emerged.

Large-scale machinery products are increasingly finding their way into a variety of fields as modern industry progresses. The strength of the product structure is very noticeable due to its large structure and important use occasions. In the research and implementation of modern engineering projects, strain measurement technology is an indispensable technology. It has a lot of potential for application and research. The strain value and its change law at various points on the structure are determined using the electrical measurement method, with a thorough understanding and grasp of the internal force distribution law and the stress situation of the body structure [2], as well as a finite element analysis and calculation of the structure. The strain value and change law at certain points on the structure are measured by the electrical measurement method in order to obtain the statistical characteristics of the stress and strain of the body structure, and the finite element analysis and body structure calculation are used to evaluate the strength of the body structure and propose a more reasonable solution. Structure must be improved. Large structures cannot be scaled up by small structures, and their strength cannot be increased linearly in proportion to the strength of small structures from a design standpoint. In addition, some special processing methods in the manufacture of large structures make large structures more effective in actual use. Intensity is full of variables [3]. After the structural strain signal output by the resistance strain gauge is amplified by the dynamic resistance strain gauge, the high-resistance output terminal is used to record the waveform of the tape drive, and the low-resistance output terminal is output to the light oscilloscope for waveform observation, monitoring, and selective recording. The electrical measurement method is a traditional method, which is widely used and the technology is very mature. Electrical measurement technology has developed rapidly due to its close integration with production practice. It has not only achieved high scientific and technological achievements in the research of theory, detection components, measurement and recording devices, test components, technology, and methods in harsh environments. Due to the large number of measurement points, long distances, and difficulty in loading, the requirements for the tester are high. There must be enough channels to meet the simultaneous measurement to avoid the trouble of repeated loading in the group test [4]. From the strain record waveform of the body structure, the time history is very arbitrary, and there is no repetitive phenomenon. However, when the overall analysis is performed using the methods of probability theory and statistical mechanics, there is a certain statistical regularity in the random process, which can be described by some statistical characteristic quantities and functions.

The painful lesson teaches us that the structure's safety performance not only affects project progress, but also puts people's safety in jeopardy, necessitating immediate structural health monitoring [5]. The accuracy of the strain value sampling is a key step that directly affects the analysis and calculation of the strength of the car body structure and whether you can draw the correct conclusion. Strain is an important metric for monitoring structural health. Strain is an important metric that reflects the structural integrity. The strain state is usually linked to a component's failure. To measure the strain on the structure's surface, the strain electrical measurement method employs a resistance strain gauge as a sensing element. From the 1930s to the present, it has evolved into a complete system. It is now a widely used method of strain measurement [6]. Because the structural damage caused by dynamic loading is often due to the dynamic pressure or strain on the structure exceeding the maximum value that the structure can withstand, regular evaluation of dynamic stress or strain is very important to effectively avoid dangerous accidents. In the strain measurement technology, the resistance strain method uses the generalized Hooke's law to find the stress by measuring the strain. The measurement accuracy is high, the sensitivity is good, and the method is simple. It has a wide range of applications and developments in the detection of building structures [7]. This article will introduce a single-chip microcomputer acquisition and processing system for dynamic (stress) and strain measurement of body structure strength. It has the characteristics of low cost, simple hardware structure, high accuracy, and reliability.

2. Related Work

Literature [8] conducted a dynamic stress test for local cracking in the cab of a new type of truck and analyzed the dynamic response of the measuring point in the time domain and frequency spectrum, pointing out the direction for cab structural improvement. The tangential wheel-rail force and lateral wheel-rail force of the power wheel axle of a 300 km/h high-speed EMU were identified using the different directions of strain gauges to be pasted and the way of forming electric bridges in [9], and a finite element model was built to obtain the load and strain relationship. The strain electrical measurement method is used in [10] to test the dynamic strain of the suspension frame under the conditions of general flat bottom, double-wheel crossing, and single-wheel crossing of the ditch, and it is combined with VC++ for data processing to obtain the stress condition and the stress when the wheel passes through the ditch. Literature [11] uses the ECAL/AMS-02 dynamic strain measurement system, a three-way resistance strain gauge, a temperature compensation sheet, and an extrapolation method to calculate the obtained strain results to obtain the maximum principal value of each point. Strain and principal stress testing have produced positive results, and strain testing technology has been improved and expanded. To reduce the impact of temperature variations on measurement results, [12] considers the impact of environmental temperature on the strain gauge in a variety of ways and employs the Huygens bridge circuit with a temperature compensation gauge to derive the expression for the heat output, which is the power output. The basic idea of the effective independence method proposed in [13] is to gradually fire off those degrees of freedom that contribute the least to the independence of the target parameters, so as to achieve the best spatial resolution of the target. Literature [14] proposed the use of perturbation analysis method to derive the relationship between sensor position and recognition error, so as to minimize the target recognition error obtained by the configured sensor network. Literature [15] developed a strain measuring instrument to solve the problem of strain measurement, which was subsequently put into production by Fairbanks and Ewing, which opened the curtain on the evolution and development of strain measuring instruments. Literature [16] combines the concept of Huston's design with the science and technology that keeps pace with the times and introduces a large number of advanced concepts into strain measurement. According to the connection state of the device and the object under test during the experiment, the strain measurement methods can be divided into contact strain measurement and noncontact strain measurement. Literature [17] embeds the optical fiber inside the composite material, resulting in a new type of optical fiber smart skin when combined with the distributed optical fiber strain measurement system. In [18] to calibrate the external parameters, the GRASP Laboratory at the University of Pennsylvania uses a straight line to represent the lane. Song Xuefeng et al. used the ground grid for calibration and introduced edge extraction in their paper [19]. In [20] image processing techniques such as the Hough transform and vanishing point detection were used to detect straight lines in both vertical and horizontal directions on the grid-like ground image, determine the position of the calibration point, and finally achieve rapid camera calibration. Li Qing et al. proposed a simple and practical three-line calibration method in [21]. This method only requires three parallel straight lines on flat ground and then determining the intersection of these three straight lines and the other three points in the image, either manually or automatically. Without a dedicated location, the camera's external parameters can be calibrated.

This article takes the single-chip microcomputer as the object, analyzes the structural strength dynamic strain measurement system, and explains its advantages. The system has a wide range of applications in the field of vehicle structural strength dynamic strain. Among them, the application of data fusion can reduce the impact of the uncertainty of each sensor and avoid the limitations of a single sensor. The fault diagnosis system of multisensor data fusion technology based on fuzzy mathematics and DS evidence theory is selected based on the decision-making layer and features. The layer-assisted method gives full play to the superiority of this algorithm.

3. Numerical Simulation

3.1. Displacement Mode Theory. In the dynamic analysis of the structure, the mode refers to the unique properties of the system structure. When a rod system such as a climbing dome is used for the analysis of the construction forming form, it is necessary to solve the mechanism displacement mode of the system. When the organization is singular, the eigenvalues of the submatrix of the control variable or the state variable in the overall balance matrix of the organization decrease, and the phenomenon of nonrow full rank occurs. During the service period of the structure, due to the influence of natural disasters, environmental loads, material aging, and other unfavorable factors, damage accumulation and resistance attenuation will occur [22]. Generally, accelerometers are often used to measure response in modal tests. Large errors may occur for light and small specimens due to the additional mass. Although the mass elimination technique can improve some accuracy, it is often not ideal. Traditional modal theory includes real modal theory and complex modal theory. It studies and describes the natural vibration characteristics of the system. Its essence is a coordinate transformation process. The displacement modal difference curve is shown in Figure 1.

Solving the dynamics equations of the structure into the sum of a series of single-degree-of-freedom dynamics equations brings great convenience to theoretical analysis or experimental research. In modern engineering, many structural systems are actually linked mechanisms, such as climbing dome, deployable structure, etc. In order to meet the needs of construction or use, it is usually necessary to obtain the movement trend of the mechanism in the current configuration. In the simulation, it is found that the existence of the mechanism's singular points makes the mechanism's movement uncertain. At the singular point, the phenomenon of "dead point" may occur, or bifurcation may occur, that is, the mechanism moves according to an undesigned motion path, and the problem of out-of-control movement occurs. This problem does not exist with the resistance wire, which is convenient to find the light weight and large bearing capacity. With the principal stress and principal strain, the transfer function measurement is as convenient as the acceleration method in identifying the displacement mode. This is undoubtedly very valuable for reducing test costs, improving test accuracy, and expanding the use of strain gauges. The real mode theory has a long history. It was developed from the undamped linear structural vibration conservative system and later applied to a variety of special structural vibration systems [23]. The orthogonal condition is its theoretical foundation. The mechanism displacement mode usually describes the movement trend of the mechanism system, and the movement trend of the mechanism system can be obtained by linear superposition of the mechanism displacement modes present in the current configuration of the mechanism system. The smallest nonzero singular value of the mechanism coordination matrix or balance matrix at the bifurcation point does not necessarily approach zero; that is, the number of mechanism displacement modes at the bifurcation point does not necessarily increase, whether it is a single-degree-of-freedom system or a multi-degree-of-freedom system.

Assuming that the linear mass $\overline{m}$ has nothing to do with the position x and the bending stiffness EI is related to the position x, the undamped free vibration equation is

$$\frac{2}{x^2} EI(x)^2 \frac{u(x,t)}{x^2} + \overline{m}^2 \frac{u(x,t)}{t^2} = 0. \quad (1)$$

According to the vibration theory, the solution of (1), that is, the free vibration displacement $u(x,t)$, can be expressed as the superposition of modes:

$$\mu(x,t) = a_{r=1}^{\circ} j_r(x) n_r(t), \quad (2)$$

where r is the mode order; $\phi_r(x)$ is the displacement mode; $n_r(t)$ is the displacement mode coordinate.

Substitute (2) into (1), and let

$$w_r^2 = -\frac{n_r^2(t)}{n_r(t)}. \quad (3)$$

Then the fourth-order differential form corresponding to the rth mode shape can be obtained:

$$j_r^{(4)}(x) = \frac{w_r^2 \overline{m}}{EI(x)} j_r(x) - \frac{2EI\varphi(x)}{EI(x)} j_r^{ii}(x) - \frac{EI^{ii}(x)}{EI(x)} j_r^2(x). \quad (4)$$

where w_r is a function of the generalized coordinates corresponding to the rth order.

If local damage occurs, the bending stiffness will also be reduced to a certain extent; that is, the stiffness distribution is no longer a constant, but a variable related to the position. The following functions are used here to describe the damage mode:

When injury occurs, $EI(x) = EI_0(1 - a\cos^2 t)$, where

$$(1-b)x_c < x < (1-b)x_c,$$
$$t = \frac{p}{2}\frac{x - x_c^n}{bx_c}. \quad (5)$$

When the structure is intact, $EI(x) = EI_0$, where

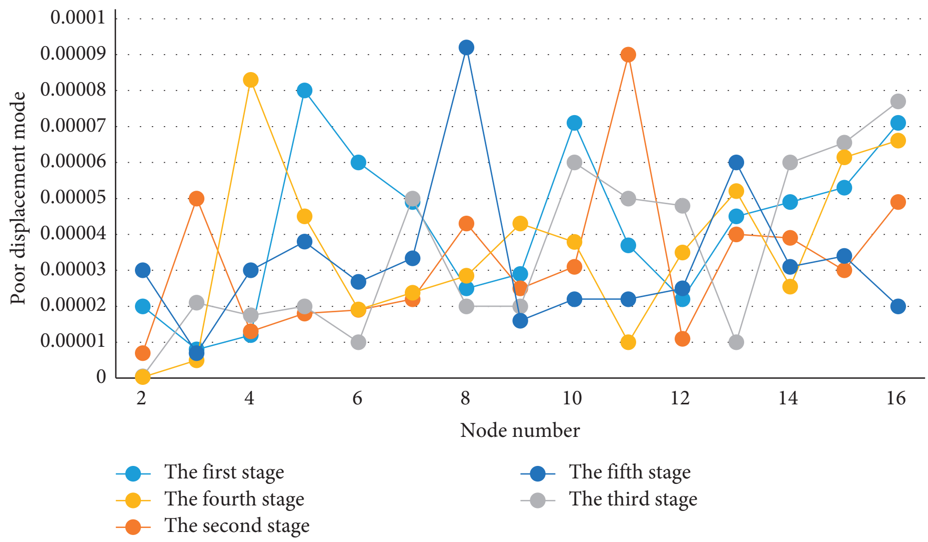

Figure 1: Displacement modal difference curve.

$$0\#x\,(1-b)x_c \text{ or } (1+b)x_c\#x\,L, \tag{6}$$

where EI_0 is the perfect bending stiffness; a, β, and n are the damage constants; L is the length; x_c is the center coordinate of the damage area.

The 4th derivative of the displacement mode cannot be measured directly in actual engineering structures, but it can be measured indirectly from the displacement mode; that is, the 4th derivative of the displacement mode can be calculated using the difference method based on the displacement mode. The following is how it was calculated:

$$j_{i,j}^{(4)}(x) = \frac{j_{i+2,j} - 4j_{i+1,j} + 6j_{i,j} - 4j_{i-1,j} + j_{i-2,j}}{l_i^4}, \tag{7}$$

where i is the node number, j is the modal order, and l_i is the length of the i unit.

Many studies on linear nonconservative nonclassical damped multi-degree-of-freedom systems have been conducted. The state space method, which has the advantage of solving the problem but the disadvantage of artificially increasing the unknown quantity, and the positional method are the two main methods. The common method of shape space has the disadvantage of not being able to solve the problem using orthogonal conditions. Under the current configuration, the mechanism displacement mode of the mechanism system is the left null space of the balance matrix of the mechanism [24]. The high-order coordination equation is always established for the non-self-stress modal mechanism, and the use of high-order coordination equations to solve the bifurcation motion path is no longer applicable. If the damage to the structure accumulates to a certain point and is not discovered and addressed in a timely manner, the damage will spread rapidly, resulting in the complete destruction of the structure. There are numerous benefits to using the strain admittance obtained from the application piece's side response as the parameter identification. On the specimen, it has no additional stiffness or quality influence. The strain gauge is small and inexpensive and can be used to measure multiple points. The measurement system is shown in Figure 2.

In general, the equivalent eigenvalue state equation of the motion equation of the linear structural vibration system can still be expressed by equation in form. Existing studies have used the singular value decomposition method (SVD method) to solve the mechanism displacement mode of the system. This method shows stable and efficient performance when the system contains few components and the balance matrix is small. To make the articulated rod system move, some nodes must be driven. The driven nodes are called driving nodes, and the rest are called driven nodes. The corresponding rods of the driving node and the driven node are called the driving rod and the driven rod, respectively. The mechanism system used in actual engineering often contains a large number of rods, and the balance matrix formed is huge and the element distribution is sparse. At this time, if the method described above is used to directly solve the mechanism displacement mode of the system, the calculation process will be slow.

3.2. Strain Mode Theory. The displacement mode is frequently obtained in modal analysis in many structural health monitoring systems today. The displacement modal analysis is frequently used when the structural deformation is analyzed, the internal force affects its change area, or there is a problem of stress concentration. It is impossible to obtain a good health monitoring effect [25]. The strain modal method's basic idea is that the vibration system's strain field can be expressed by superimposing appropriate characteristic strain fields in a certain proportion. The strain mode, like the displacement mode, reflects the structure's inherent characteristics. It is critical to analyze the stress state of the structure under dynamic load conditions when designing a structure dynamically. Strain is sensitive not only to local structural changes that affect the structure's strength and life, but also to the additional mass and rigidity caused by the

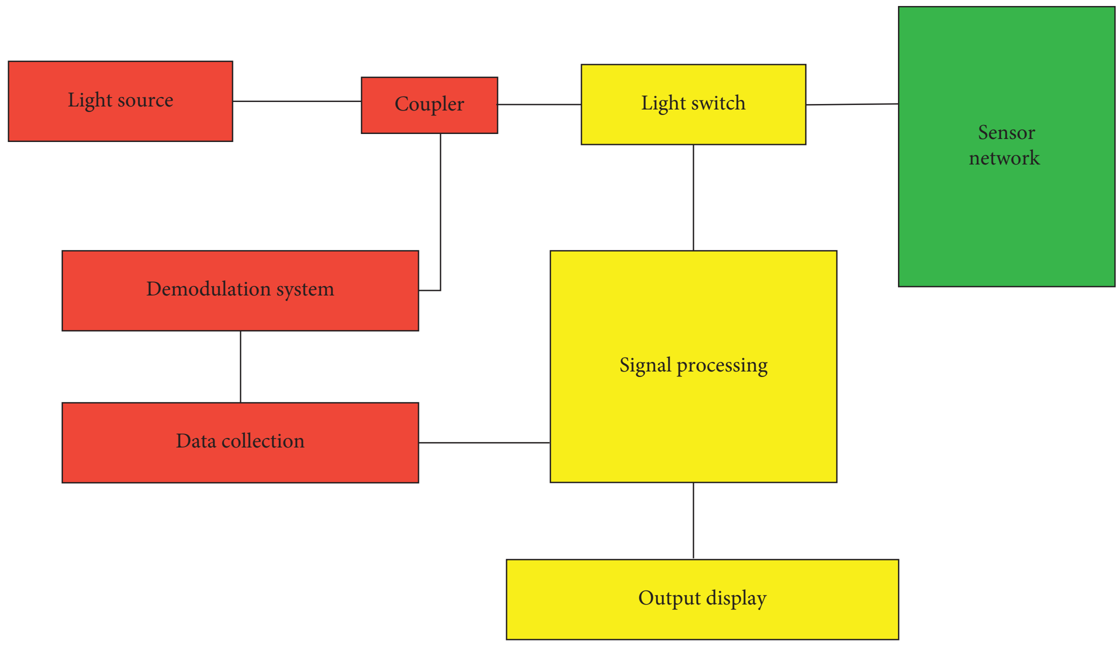

Figure 2: Block diagram of the measurement system.

resistance strain gauge sticking. Researchers are constantly exploring whether the strain response of the structure under the action of external force has a distribution law similar to the displacement response mode in order to effectively monitor the structure in all aspects. The physical significance of strain modal theory is obvious, but a more rigorous mathematical discourse has yet to emerge. The theory of strain modal is still being developed at this time. Curvature modal measurement is a method for indirectly detecting stress and strain that avoids the limitations of strain gauge measurement by using displacement measurement. The actual stress is determined by strain measurement. Strain modal testing technology has broad application prospects for structural damage identification research [26]. Traditional nondestructive testing techniques, such as ultrasonic method, shock echo method, acoustic emission, infrared method, and radar method, are all local damage diagnosis techniques, which require a priori knowledge of the damage site and are suitable for local detection, but in fact, it is very difficult to detect all parts of the structure. Compared with the displacement mode, the strain mode is another manifestation of the same energy balance state. It can be seen from the simulation results that the natural frequency and modal changes after damage are closely related to the location of the damage point. Establishing the calculation model of strain response directly will make the estimation of dynamic stress more accurate. The vibration diagnosis technology based on vibration theory is to analyze the natural frequency, damping, and modal vibration characteristics of the structure by testing the response of the structure under dynamic load and then to diagnose the location and degree of structural damage. There are two ways to make the inversion result unique: (1) add mathematical constraints; (2) add physical constraints. When the damage point is located at the mode node, the change of the natural frequency, mode, and mode difference of this order is extremely small. The function of the dynamic strain measurement system is shown in Figure 3.

This should be paid attention to when actually detecting damage. Strain is more sensitive to local structural changes (such as local small holes, cut grooves) that will have an important impact on the strength and life of the structure, while displacement responds slightly to this. Since the dynamic characteristics of the structure are only related to its inherent properties and reflect the overall behavior of the structure and have nothing to do with external conditions such as loads, the vibration diagnosis technology has the ability to diagnose global damage, which can make accurate safety assessments for the structure. The percentage of curvature mode change is much higher than that of displacement mode. Regardless of displacement mode or curvature mode, higher-order modes can better reflect the existence and location of damage than low-order modes. Direct modal analysis of strain response is more important for local stress or local damage. The problem of selecting the amount of damage identification, that is, deciding which parameters can be used as the basis for better identifying and calibrating the damage location and extent of the structure, is the first step in structural damage diagnosis. With more experience, the ability to identify and locate damage to a specific structure will improve steadily [27]. Obviously, if the measurement is repeated with an artificial neural network as the learning tool, we can design an intelligent structural fault diagnosis system with a self-evolving knowledge base. The low-order amplitude (generally inversely proportional to the square of its natural circular frequency) that can be excited by the same exciting force is much smaller than the high-order amplitude. Because the resistance strain gauge has a small mass, the additional stiffness caused by the paste is also small, making it ideal for measuring and analyzing thin and

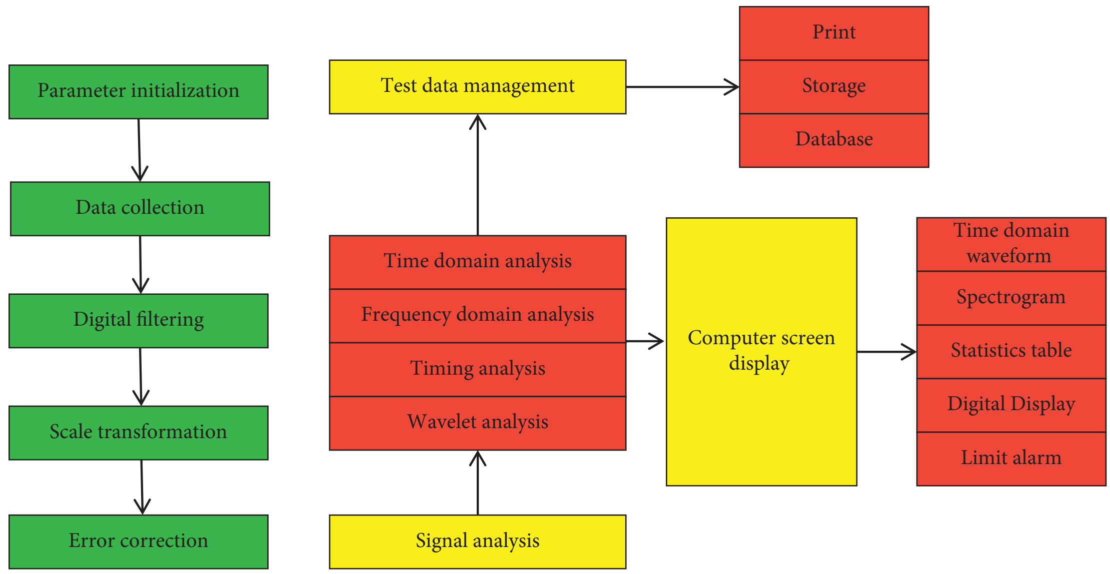

Figure 3: Functional block diagram of dynamic strain measurement system.

small structures. The amount of damage identification must change monotonously with the increase in the degree of damage to determine the degree of damage to the structure. As a result, some damage identification indicators will be produced by determining the location of the damage and calibrating the degree of damage. Limitations: Vibration characteristics are now a widely used and powerful diagnostic method for fault diagnosis and monitoring, but it primarily focuses on the diagnosis of mechanical equipment or mechanisms, component failures, and general engineering structures that bear or transmit loads. There has not been much research done.

3.3. Numerical Simulation. After knowing the displacement response mode of the fixed beam, in order to obtain the subsequent full-field dynamic strain, we must also know the strain response mode. According to the strain mode theory, the strain response mode can be obtained by direct deduction. Mode shape: In order to predict the safety state of the structural system during the dynamic response process, it is necessary to analyze the dynamic reliability of the structural system. The uncertainty of the actual structure's natural frequency will not guarantee the frequency tuning of the TMD. The cumulative energy that can reasonably explain the cumulative damage to the structure during vibration has become an important object of energy method research, but the pure cumulative energy spectrum can hardly reflect the tendency of vibration to damage the structure's impulse type. The anchor rod is usually analyzed as an axial rod unit with rough surface. However, in the joint slope reinforcement, it is more reasonable to consider the axial and lateral effects of the anchor rod due to the dislocation of the joint surface. The random factor method is used to analyze the dynamic characteristics and dynamic response of the random rigid frame structure. Starting from the frequency domain expression of the random response of the structure, using the algebraic synthesis method and the moment method to solve the numerical characteristics of random variables, the random parameter rigid frame structure is derived. The frequency tuning sensitivity of TMD is an important practical issue. The instantaneous input energy is related to the first destruction of the structure. In the joint slope engineering, due to the dislocation of the joint, the anchor rod will inevitably bear a certain lateral force, and its importance is no less than the axial force. Short-period structures are controlled by steady-state vibrations and are prone to cumulative damage and damage. For long-period structures, the total displacement is controlled by transient vibrations. In terms of values, the displacement generated by the transient vibration term is not only much larger than the resonance displacement, and the attenuation is very high. It is slow and is also affected by vibration. It is necessary to conduct a comprehensive analysis of the force of the anchor element in the joint slope, so that it can exert not only the axial force performance, but also the lateral force performance [28]. In transient vibration terms, the maximum displacement of the structure is more likely to exceed the damage standard, and the damage is often one-time and sudden. The numerical simulation method has the characteristics of low cost, short time, strong repeatability, and great flexibility. Especially for the qualitative study of the displacement field effect of huge rock mass structures, it is more unique. It can be discussed from the macro overall trend, with the changing law of the field effect of the rock mass. The above is of great significance to the design of structural control system in the future.

The use of modal analysis technology to analyze the dynamic characteristics of automobile structures is a mature technology that has been used by many units both at home and abroad. The dynamic stress-strain distribution of an automobile structure determines its fatigue damage. As a result, in recent years, the calculation or experimentation of the structure's dynamic strain field has gotten a lot of attention. The structure's experimental stress analysis is carried out under simulated conditions, an efficient method for determining static strength. The dynamic allowable stress of the structure is often calculated by dividing the static allowable stress of the structure by a chosen safety factor during the vehicle design stage. The results of the static experimental stress analysis are examined. The key to establishing the model is to simulate the nonlinearity of the moving boundary using the contact and target elements in order to achieve the lift-off of the tank bottom. The vehicle structure's use characteristics dictate that it is always subjected to dynamic random excitation of the road surface in actual use, and the dynamic allowable stress of the structure under dynamic load is much lower than the static allowable stress. Engineers work on building structures. We are more concerned about the distribution of stress and strain from the standpoint of strength and fatigue. The dynamic strain/stress field's basic idea is that the perturbed system's strain field can be superimposed and expressed in a proportion by an appropriate characteristic strain field. The so-called "strain mode" is the characteristic strain field. The dynamic strain of the structure is measured by the test-time. The procedure can take a long time. The original analog signal must be discretized sampling in order to perform effective signal processing. The dynamic strain of each measurement point of the frame structure is generally normally distributed due to the random nature of the road surface excitation. It is important to see if the maximum dynamic stress exceeds the allowable stress during the structure's strength check, as well as the strain distribution. It can be obtained through a differential deformation displacement operation. Alternatively, the strain distribution obtained by integration can be thought of as the deformation displacement. One row and one column of the strain transfer function matrix must be measured when building the dynamic strain response model of the structure, and both modal models contain the same modal parameters. The maximum stress value in each sample is a random variable that characterizes the maximum stress distribution at the measuring point because the sample is normally random.

4. Cantilever Beam Experiment Verification

4.1. Strain Electrical Measurement. Electrical strain measurement is a traditional method of measuring strain that is widely used and has a well-developed technology. Strain gauges are used as sensitive components in the strain electrical measurement method. It measures strain using the strain gauge's sensitive grid's strain resistance effect. During the actual measurement, the strain gauge is adhered to the test piece. Its benefits include high measurement accuracy and sensitivity, a wide measurement range, continuous measurement and recording, and long-distance measurement; it can also be easily integrated into a control system to automate the manufacturing process. The strain electrical measurement method is currently used to measure the longitudinal stress of the rail primarily in the United Kingdom, the United States, Japan, and other countries. The general procedure for measuring strain with a resistance strain gauge (strain gauge) is to paste or install the strain gauge on the surface of the component to be measured and then connect it to the measuring circuit (bridge or potentiometer circuit). The strain increases as the component is deformed. The chip's sensitive grid deforms as well, changing the resistance value. The damping coefficient test curve is shown in Figure 4.

The general resistance strain gauge is mainly composed of five parts: sensitive grid, adhesive, lead, base, and cover sheet. When measuring in a temperature-changing environment, measures must be taken to eliminate the influence of the heat output of the strain gauge in order to ensure the accuracy of the measurement. There are various measurement systems, which are directly related to the nature of the measured nonelectricity and the type of converter used. The overall design procedure of the system is shown as in Figure 5.

Commonly used converters can only convert a certain mechanical quantity into electricity. For example, strain gauges can only convert strain into resistance. In order to expand its measurement range, a mechanical converter is often added before the converter to change the required measurement. The mechanical quantity is converted into a mechanical quantity capable of driving the converter. The measured locked rail temperature is also relative to the locked rail temperature at the cleared temperature, and the longitudinal stress of the rail measured by the strain electrical measurement method is relative to the rail stress state after the strain sensor is cleared. The change in resistance value should be proportional to the component's surface. The signal generated by the strain gauge's resistance change is output by the measuring circuit. It is indicated or recorded by the indicating instrument or recording instrument after being amplified by the amplifier circuit. The sensitive grid is a monofilament or grid-like body made of metal wire or semiconductor material whose purpose is to convert changes in strain into changes in resistance. In an environment with large temperature changes, the self-compensation method uses a special treatment process or a method of connecting two materials with a resistance temperature coefficient in series to make a sensitive grid, so the heat output of this method is not high. A converter composed of certain elements or components can produce electrical effects under the action of nonelectricity, that is, converting nonelectricity into electricity. For example, the commonly used strain gauge is a kind of converter; it will produce the change of resistance under the action of strain and convert the amount of strain into the amount of resistance. Since the radius of the rounded corner of the connecting rod journal is relatively small, and the part covered by the sensitive grid of the same length is relatively large, the error of the strain electrical measurement is also larger than that at the rounded corner of the main journal, as shown in Figure 6.

Due to the influence of factors such as rain and snow, as well as other factors such as impact and vibration when the train passes by, higher requirements for the moisture-proof,

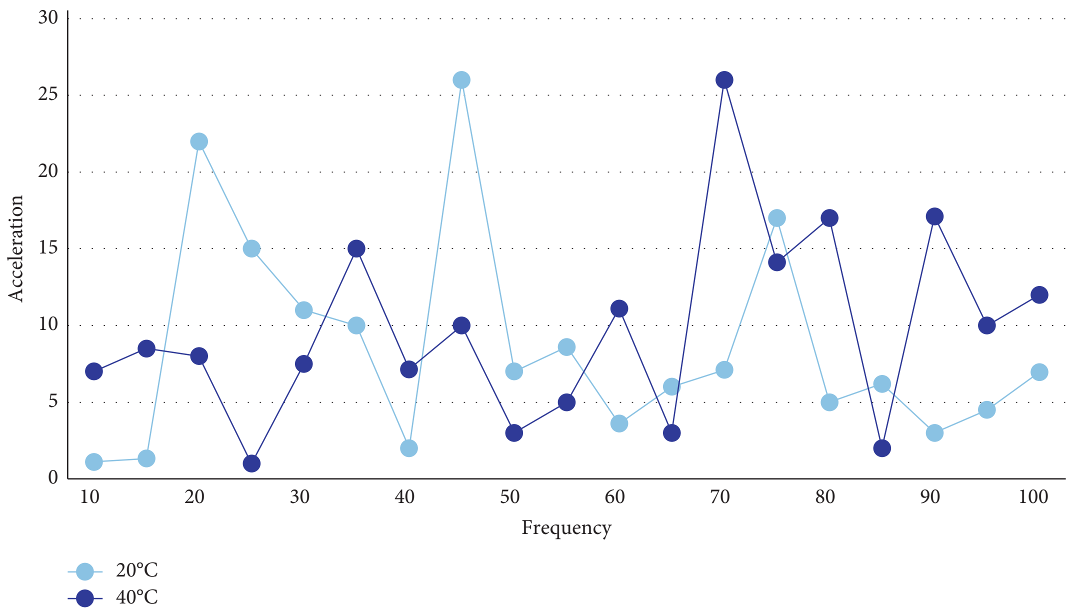

Figure 4: Damping coefficient test curve.

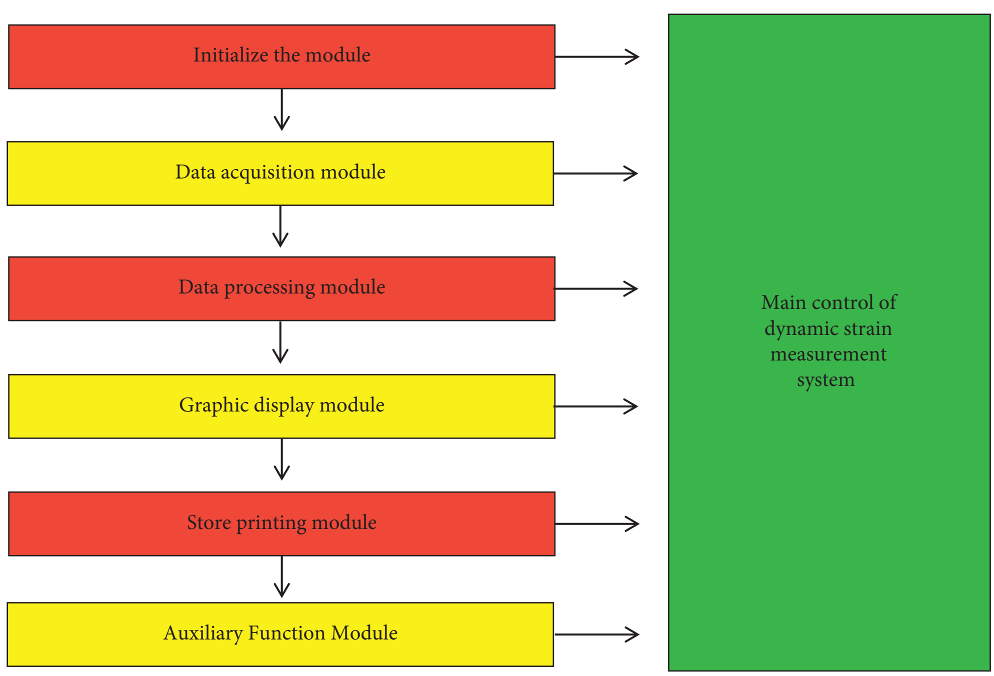

Figure 5: System overall design procedure.

antistripping, and long-term use performance of the sensor system are put forward on the seamless rail line in nature. The strain gauges' measuring points are chosen based on the results of the previous finite element method's simulation and calculation, and the strain gauges are deployed in the larger stress area and part of the abnormal stress area. The strain gauge's job is to convert changes in strain into changes in resistance, but it also has to convert the relative change in resistance into changes in voltage or current so that it can be measured by an electric measuring instrument. The thermal element method involves having the thermal element generate a signal that is of the same value and opposite sign as the strain gauge's heat output in order to cancel it out. This method necessitates the use of additional circuits, as well as a lengthy and time-consuming implementation process. The mechanical converter and the converter are commonly referred to as the sensor because they are assembled together, with load cell, acceleration sensor, and so on. The strain electrical measurement method must meet stringent requirements for longitudinal stress accuracy, applicability, and long-term online monitoring.

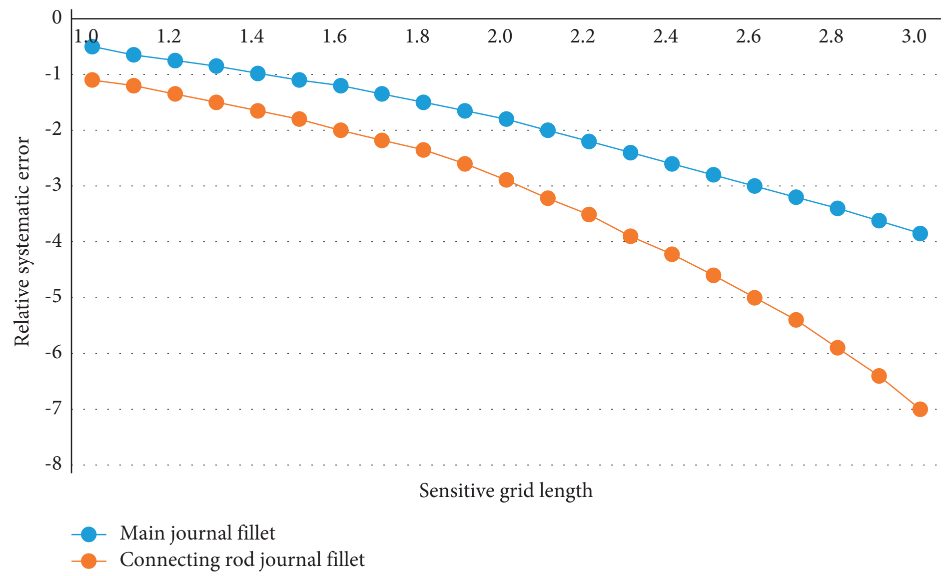

Figure 6: The influence of the length of the sensitive grid on the strain measurement error.

4.2. Experimental Design. In the test, one end of the cantilever beam is fixed on the experimental platform, and the other end is free, and the circular mark point is pasted on the side of the cantilever beam. The purpose is to use the binocular camera to capture the vibration image of the mark point and perform three-dimensional reconstruction, with vibration displacement of the mark point. In order to use the rectangular microcantilever to measure the fluid density, this paper adopts the mode superposition method according to the force balance principle to derive the theoretical relationship between the first-order resonance frequency and the fluid density of the rectangular microcantilever with one end fixed and the other free end, using ANSYS software. The resonance frequency of the microcantilever in different densities of n-heptane and isooctane is simulated and analyzed. Once the flexible member is excited, because of its tiny structural damping, the vibration of the flexible member will be difficult to stop in a short time, and the vibration of the flexible member will cause resonance, which will eventually affect the working accuracy and service life. The system performs sinusoidal sweep excitation on the specimen to obtain the response characteristics of the specimen and analyzes the data to obtain the coefficient of the structure specimen. In order to analyze the influence of different piezoelectric materials as the piezoelectric layer on the sensitivity of the piezoelectric microcantilever, piezoelectric ceramics and PZT-5H are used as the piezoelectric layer materials of the piezoelectric microcantilever, and piezoelectric analysis is carried out by ANSYS, as shown in Figure 7.

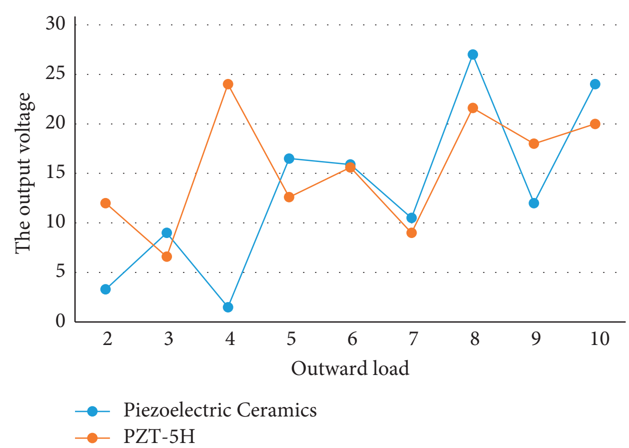

Figure 7: Output voltage when two piezoelectric materials are used as the piezoelectric layer.

Microcantilever is a typical movable microstructure device. Its length and width are generally in the micron rang, and the thickness is in the submicron range. According to different applications, it can be used such as monocrystalline silicon, polycrystalline silicon, silicon dioxide, aluminum, etc. It is made of three kinds of materials, because it has the characteristics of simple preparation process and strong ductility in the application field; it occupies an important position in the microelectromechanical system. By superimposing the vacuum mode of the microcantilever to replace the fluid-structure coupling mode of the microcantilever, the influence of the fluid on the microcantilever is converted into fluid dynamic pressure, and the vibration differential equation is solved by the orthogonality of the vacuum mode. The relationship between the resonance frequency of the cantilever beam and the fluid density is obtained. The general idea of the finite element method is to first divide a continuous area or object into finite elements (and these elements bear equivalent nodal loads) and then build an “element matrix” based on the relationship between the nodes of these elements to solve the problem. The external additional mass causes the natural frequency of the microcantilever to change, and the quality detection can be achieved by measuring the frequency shift of the microcantilever. Based on this principle, a micromass spectrometer can be made to detect the quality of single molecules and single cells and so on. In a natural law system, the total mechanical energy is conserved, so when the system is vibrating freely, potential energy and kinetic energy are converted mutually without energy loss, so that the system will maintain a constant amplitude structural vibration. Under normal pressure, the resonance frequency of the rectangular microcantilever in n-heptane and isooctane was measured experimentally, as shown in Figure 8.

Active control technology is the most effective way to reduce the vibration of a flexible structure. The piezoelectric sensor and actuator are integrated in the flexible cantilever beam, making it a smart structure, and the study of its vibration suppression characteristics will have practical significance for the active control of flexible beam vibration. The computer software sends a drive signal from the controller to the power amplifier, which amplifies the signal and drives the vibration exciter (vibration table) to move according to the required vibration control spectrum. The benefit of using the finite element method to simulate a micropiezoelectric cantilever is that it can discretize the object into a set of finite simple elements, which can then be used to simulate or approximate the original object, reducing a continuous problem to a discrete problem. Perform analysis to obtain the entire object's analysis structure. Thermal stress analysis, thermal structure analysis, thermoelectric analysis, thermal fluid analysis, magnetocaloric analysis, magnetic structure analysis, induction heating analysis, induction oscillation analysis, electromagnetic circuit analysis, and electrical structure analysis are just some of the multiphysics analyses available in ANSYS. The peak-to-peak output voltage of the vibration frequency (20Hz–200 Hz) is used, as well as the direct output of each cantilever beam piezoelectric slice and the connection modes of parallel and series. The maximum output voltage of each in parallel and series connection is compared. The test results are shown in Figure 9.

Regardless of whether the static mode or the dynamic mode is used for experimental research, a reference experiment is usually included, that is to say, a microcantilever with the same mechanical characteristics without surface functionalization is tested at the same time, and the difference between the two is compared. The signal gets the signal under test. Damping is definitely there and it is impossible to avoid. This will affect the conversion of mechanical energy, and the energy will slowly decay, so that the constant amplitude vibration cannot be maintained. This kind of mechanical vibration is called damped free vibration. Gray prediction is a prediction method that analyzes the dynamic behavior and operating trend of the object. It has the advantages of low model requirements, fewer online estimation parameters, convenient calculation, good comprehensive control effects, and strong robustness. It is currently in the field of industrial process control being widely used.

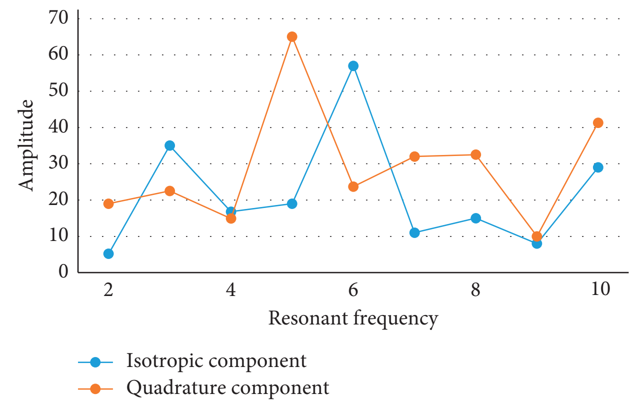

Figure 8: Amplitude-frequency curve of microcantilever in n-heptane.

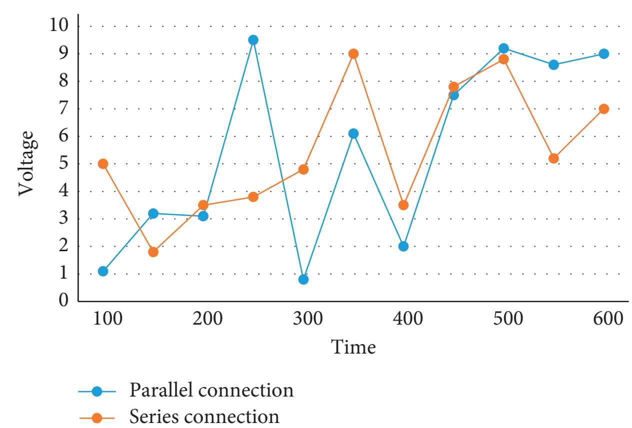

Figure 9: The relationship between output voltage and time.

4.3. Camera Calibration. Before performing the experiment, it is necessary to determine the two cameras for calibration, that is, to determine their internal and external parameters. The purpose of the camera calibration is to establish the relationship between the three-dimensional object point in the space and the two-dimensional image point of the pixel coordinate system, and the calibration result is directly related to the accuracy of the vision system. Internal and external parameter calibration are the two types of camera calibration. Fixed-focus lenses are used in all vehicle-mounted cameras, and their internal parameters do not change after one calibration. The calibration of external parameters is the only thing that needs to be considered. A one-dimensional calibration object with an infrared reflective marking ball installed at both ends and in the middle is made to solve the problem of camera calibration in the process of photoelectric detection of motion parameters. The effective focal length of the camera, the principal point of the optical center, and the lens distortion coefficient of the camera are among the internal parameters. External parameters are primarily the position transformation between the camera coordinate system and the world coordinate system, and these are the main parameters of each camera. The rotation matrix and the translation matrix are the two most important position transformation parameters between the two cameras. The camera obtains a two-dimensional image of the surface of the ground object, with the ultimate goal of obtaining the object's three-dimensional spatial information. As a result, research into how to solve three-dimensional spatial information of the ground object of interest in real time using the on-board 3D data acquisition system is required. The key content here is camera calibration. On the other hand, we investigate how to improve the accuracy of the solution model by optimizing it. The compensation algorithm can significantly improve the measurement accuracy of the vehicle's yaw angle and lateral displacement, as shown in Figure 10.

The feature point matching method uses a calibration board with special graphics to extract the three-dimensional points collected by the Lidar and the two-dimensional image points obtained by the corresponding camera, establish a constraint equation, and optimize the calculation of the camera pose. Its essence is the PNP (perspective n-point) question. When calibrating the camera, if too much nonlinear distortion is considered in the calculation process, it will lead to the introduction of too many nonlinear parameters in the calculation process, which will affect the calibration accuracy and cause other opposite effects. On the assumption that the road is flat, the following two situations will generally occur during the normal driving of the vehicle: local bumps on the road surface cause small bumps and vibrations in the vertical direction of the vehicle body. One-dimensional calibration object, a calibration method based on one-dimensional calibration object, has the advantages of low cost, being easy to move, and being suitable for on-site online calibration, and more importantly, it can solve the occlusion problem in multicamera occasions. The checkerboard calibration method uses a two-dimensional checkerboard as the calibration board and changes the position information between the calibration board and the camera by continuously rotating the calibration board. The relative orientation direct solution method entails expanding the coplanar equation and performing a linear transformation, then solving the relative orientation elements, and constructing a relative three-dimensional model. This method employs linear transformation; the solution is quick, but the outcome is not precise. The plane calibration template fits the straight line with Lidar points to find the intersection point and then manually marks the position of the characteristic points on the calibration board according to the scale to find the image coordinates. The primary goal of feature point extraction is to precisely determine the location of each feature point in the image so that it can be calibrated in the appropriate spatial coordinates. Reduce the relative solid model to a specific scale by incorporating it into the ground coordinate system. The relative solid model and the coordinate system's translation and rotation parameters, as well as the model scale factor, are solved in the on-board 3D data acquisition system camera pair calibration. A measuring device, independent of the front-view camera, was designed to accurately and quickly measure the vehicle's yaw angle and lateral deviation in order to verify the actual effect of the compensation algorithm in the driving of the vehicle.

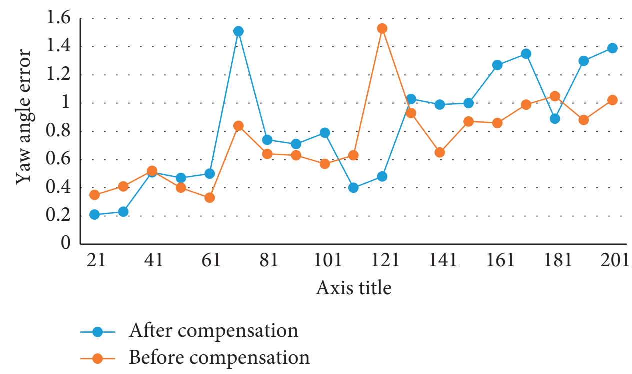

FIGURE 10: Actual measurement error of yaw angle.

5. Conclusions

Strain measurement is a traditional technology. Although the secondary instrument has new methods, such as automatic balance, computer postprocessing, etc., its essential things have not changed. The key to improving test accuracy is still this part of the instrument, namely, attaching strain gauges and soldering wires. The main features of the vehicle structure strength single-chip microcomputer data acquisition and processing system, as compared to the conventional test system, are greatly reduced test system cost, greatly improved measurement accuracy and detection speed, and diversified processing functions, and all of them can be obtained as soon as the test is completed. Collect information and test results. The measuring points for dynamic strain measurements of the car body structure's strength are chosen based on the results of static tests (static bending and static torsion), that is, the maximum stress value and location of the car's main components in a static state due to its own weight and load. The dynamic strain collector's intelligent and portable design will have a wide range of applications in the stress measurement of engineering structures such as dams, space shuttles, ship structures, and power generation equipment.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Research on Online and Offline Mixed Teaching Practice Based on College Film and Television Literature Course

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With the rapid development of new media technology, the demand for applied professional film and television talents in China's film and television industry is getting higher and higher, especially the comprehensive practical ability. In the Internet age, information technology has been widely used. It is integrated into people's lives with the unique characteristics of interaction and communication among all employees, and opens up a new mode of work, study and life with Internet as the medium. Under the new situation, all kinds of schools at all levels also make full and active use of the Internet for online teaching. In the past, the quality monitoring work focused on theoretical teaching. However, in the face of online and offline mixed practice teaching, there are bound to be many problems and deficiencies when using the theoretical teaching quality monitoring system. This paper mainly discusses the application of online and offline mixed tutorial mode in film and television literature course from the aspects of task-oriented teaching content, application of classroom teaching methods, diversification and dynamics of evaluation methods, etc., hoping to provide reference for college teachers who implement online and offline mixed teaching.

1. Introduction

Human society has entered the era of information society and knowledge economy at the end of the twentieth century. The mass media is credited with ushering in this era. Film and television are examples of rapidly evolving mass media in the twentieth century [1]. With the rapid advancement of new medium technology, the demand for application-oriented professional film and television talents in China's film and television industry is growing, particularly for those with a broad range of practical skills [2]. In the process of cultivating students, film and television majors must strengthen the cultivation of students' cognition and practical ability in addition to imparting basic theories [3]. As the most vigorous modern comprehensive art, film and television art is based on the development of sci & tech from birth to development. It is a new artistic flower open on the tree of modern sci & tech [4]. With the application of a series of high and new technologies such as Internet, digital technology, multimedia technology and interactive TV, the charm of film and television art is increasing day by day [5]. Compared with the traditional poetry, novel, prose and drama, film and television literature should be said to be a new literary style. People's understanding of film and television literature is not only inferior to the traditional literary style, but also inferior to the understanding of film and television art [6]. In the Internet age, information technology (IT) has been widely used. It integrates into people's life with its unique characteristics of full staff interaction and communication, and opens a new mode of work, study and life with the Internet as the media. Under the new situation, all kinds of schools at all levels also make full and active use of the Internet for online teaching [7].

Different from most tutorial modes dominated by online network teaching, hybrid teaching is not confined to a single teaching method, but through the combination of online digital education and offline classroom teaching, emphasizing student-centered and giving full play to the enthusiasm, initiative and creativity of students as learning subjects, It advocates using online educational resources and IT to promote curriculum teaching and improve learning effect [8, 9]. The core meaning of mixed teaching does not lie in the unique innovation of teaching means, but in whether the student-centered learning goal is realized. Therefore, all means that help to improve the learning effect can be used, which undoubtedly greatly expands the inclusiveness of mixed teaching [10]. At present, online and offline mixed teaching is a new tutorial mode, and practical teaching is in the stage of exploration and exploration [11]. In the past, the quality monitoring work focused on theoretical teaching, while in the face of online and offline mixed practical teaching links, there must be many problems and deficiencies in using the quality monitoring system of theoretical teaching [12]. This paper discusses the application of online and offline mixed tutorial mode in film and television literature courses, mainly from the aspects of task-based teaching content, the application of divided classroom teaching method, diversified and dynamic evaluation methods, hoping to provide reference for university teachers who implement online and offline mixed teaching.

Film and television literature is a relatively broad concept. It is the collective name and abbreviation of film literature and television literature. It is a new literary style with the prosperity of film and television art [13]. Film and television art has more audience groups than other arts, which is unmatched by any other art category, such as poetry, novel, drama, etc. the new era of film and television art has come [14]. Films, TV dramas and other film and television art works not only penetrate into human life style and change human concept and consciousness, but also give birth to a new cultural form such as film and television literature [15]. The student-centered hybrid tutorial model can effectively integrate all kinds of teaching resources and teaching forms into the classroom [16]. This rich and diverse teaching form is exactly what is urgently needed in the writing classroom aimed at stimulating students' enthusiasm and creativity [17]. The organic combination of online information-based teaching means and traditional classroom teaching can effectively make up for the poor interaction between teachers and students by using online teaching alone, and meet the needs of writing courses in simulating situations and inspiring emotional resonance. Based on the film and television literature course, this study explores the online and offline mixed tutorial mode, how to flexibly combine the online course with the traditional classroom, enhance students' knowledge application ability and integration ability, and provide new ideas and experience for the mathematics teaching reform in the classroom of universities.

2. Related work

Film and television literature is a relatively broad concept, the collective name and abbreviation of film literature and television literature, and a new literary style that appears with the prosperity of film and television art [18]. Literature [19] mentions that film and television literature is also an auditory art, and all descriptions of dialogue, monologue and narration should take into account the needs of pictures, with pictures as the main body of expression, and music, language and sound are all to expand and strengthen the expressive force of pictures. According to the literature [20], because film and television art is developed on the basis of photography, it is necessary to truly reproduce the object and its movement, so that it can approach life to the maximum extent in terms of expression form, and the screen image is not only visible but also realistic. Film and television literature, according to Literature [21], is a television art work that vividly reflects life, shapes characters, and expresses emotions through special screen modelling means, and imparts literary aesthetic taste to audiences. From the standpoint of the birth process of film and television literature, literature, as an artistic form, has become an organic part of a new type of literature as it has been absorbed and integrated, according to Literature [22]. Teachers should strive to meet the needs of curriculum reform, continue to learn, update their ideas, and improve their own cultural literacy, according to literature [23]. We should also study textbooks carefully and strengthen the inspiration and guidance provided to students in the cooperation and interaction of an equal dialogue with them. The mixed tutorial mode is introduced into the teaching of writing courses at universities in this paper, and it is sorted out and summarised after being combined with the actual teaching effect.

3. Connotation of online and offline mixed tutorial mode

As a kind of integrated tutorial mode, blended teaching is more flexible in learning methods. Through the online and offline hybrid tutorial mode, students can search relevant learning materials through the Internet anytime and anywhere, so as to learn in fragmented time [24]. And prepare or review according to the materials pushed by the teacher, so as to lay the foundation for the teacher's explanation of knowledge in class. Teachers and students strengthen the interaction and exchange of knowledge understanding in class, and can prepare relevant information for students to strengthen review and expansion after class. The purpose of hybrid teaching is to combine the advantages of traditional teaching methods with the advantages of network learning, so as to realize their complementary advantages and obtain better teaching results. From the perspective of teaching platform, the hybrid tutorial mode is mainly implemented based on MOOC (massive open online courses) platform and university network teaching platform. MOOC has the advantages of large scale, high efficiency, low cost, excellent teachers and flexible time, but there are still deficiencies in the depth of knowledge interaction. Although MOOC can preach and teach, it can not effectively solve doubts and achieve efficient and in-depth knowledge interaction.

Teachers cannot provide one-on-one personalised learning guidance to learners in the process of knowledge interaction between teaching and learning in the MOOC context, and learners find it difficult to conduct in-depth knowledge exchange. Knowledge interaction links like discussion are difficult to match. As a result, it is critical to supplement offline instruction to compensate for the shortcomings of online instruction. However, in order to achieve the effect of complementary advantages, online and offline teaching should be focused on each other, and the proportions should be appropriate and reasonable [25]. The mixed tutorial model's theoretical foundation is to create a relatively stable, systematic, and theoretical tutorial model around a specific theme in teaching activities, guided by specific teaching ideas. Students' learning enthusiasm can be mobilised through rich online learning resources and communication modes. At the same time, incorporating various offline activities into online courses can help to improve the teaching effect while also increasing students' interest in learning [26]. With the application of online and offline hybrid tutorial mode in Universities, it not only eliminates the limitations of traditional tutorial mode in time and space, but also makes teachers access to more high-quality demonstration curriculum resources, thus promoting the integration of teaching materials and lesson preparation methods. The learning process should be student-centered, and students must actively participate in the whole learning process. The second is that knowledge is the social construction agreed by individuals and others through consultation. Therefore, in the learning process, we should pay attention to the interactive learning method and change the current situation of students' passive acceptance of knowledge.

4. Significance of film and television literature teaching

4.1. Promoting Chinese Literature Education. In addition to strengthening the teaching of traditional poetry, novels, essays and dramatic literature styles, literature also needs to add fresh blood. For contemporary middle school students, film and television art should be said to be the most vital. It combines various artistic features such as literature, music, dance, art, sculpture, etc., coupled with computer synthesis and other scientific and technological means, whether it is dynamic, texture or sound effect, it is quite excellent. Appreciating film and television literature entails having a certain level of artistic achievement, a certain understanding of the aesthetic law of film and television art, and the appreciator's own life accumulation and experience, so that he can gain a deeper understanding of all aspects of film and television literature and, as a result, be psychologically happy. The film and television scripts themselves are based on literature or are closely related to it. A wide range of literary techniques for reflecting and expressing life, such as narrative techniques, structural styles, novel expression skills, lyricism in poems, and artistic conception in prose, all provide food for the creation of film and television literature. One of the best platforms for implementing comprehensive Chinese activities is through the teaching of film and television literature works. It can help students develop rich associations and imagination while reading, as well as connect with the works' image and artistic conception. It enables students to explore the works' rich connotation and deep meaning, as well as their own unique feelings and creative interpretations.

4.2. Improve students' cultural literacy. In the process of learning film and television literary works, students' listening, speaking, reading and writing abilities are improved, their aesthetic ability is constantly strengthened, and their artistic taste is gradually improved, which helps to cultivate students' practical ability and innovative spirit, and help to form students' good personality and sound personality. Therefore, the teaching of film and television literary works should be placed in an important position in literature education. Students should be instructed to read rich and excellent literary works, acquire necessary literary knowledge, cultivate and improve their literary literacy, and at the same time, incorporate ideological education into them to cultivate lofty ideals and ambitions. The education of literature development and achievements in common sense should rely on colorful literary styles such as poetry, prose, novel, drama, film and television literature, etc., and enter students' vision and thoughts, and a considerable part of the content will become their lifelong cultural wealth. Reading and appreciation of literary works is the focus and center of literary education, which includes reading and appreciation of ancient, modern and contemporary Chinese poems, essays, novels, dramas, film and television literary works and excellent foreign literary works, which is the main body of literary education. Students' understanding of the original novel and our explanation of the adapted film and television literature works can refer to each other, and the similarities and differences formed in the process can help students form their initial feelings and experience material accumulation of film and television literature works, thus leading them to re-recognize the shaping and deepening functions of film and television literature.

5. Present situation of mixed teaching of film and television literature

At present, when we teach film and television literature works, the way is extremely monotonous, which basically ignores the unique characteristics of film and television literature. Instead, we simply teach film and television literature works as general literature works, and more often analyze the writing and writing techniques from the perspective of language, resulting in that the unique appeal of film and television literature works has not been fully exerted, which can not really impress students and enhance the aesthetic ability of literature.

5.1. Simplification of film and television literature teaching content. At present, the outstanding problem in Chinese teaching is not the incorrect understanding of works, but the lack of full respect for students' subjectivity in the teaching process and the lack of more independent space for students. Teachers don't guide and encourage students to actively examine society and life with their own eyes, but always instill existing fixed answers into students, which is mandatory and oppressive. The film and television literature course in universities is different from other courses in content, which requires not only deep excavation of literary works based on writing background, historical environment, characters' personality, expression of emotions, etc., but also reasonable research and application of various theoretical knowledge that is convenient for exploring profound meaning. This kind of online and offline mixed teaching for literature will be difficult to achieve more rational application of teaching resources, which will make it difficult to display its value. Although students have a strong interest in film and television literature, most of the teachers, starting from the practical purpose of dealing with the examination, led the students to walk through the classroom in a superficial way. Students only remember what the examination contents need to be memorized, but they have little knowledge of film and television art and film and television literature, let alone deeply appreciate film and television literature works.

5.2. Poor teaching process design. The design of the teaching process determines not only the quality of the teaching effect, but also the quality of the teaching process organisation in the online and offline mixed tutorial mode. The works should have a three-dimensional sense and image, a broad thinking space, and promote thinking activities, rather than being limited to the words themselves. Furthermore, film and television literary works use a variety of expressive techniques. Fully digging and explaining can also help students gain a better understanding of other fields besides Chinese, as well as inspire them and provide them with a variety of writing opportunities. Students' self-study before class, teachers' deepening in class, and students' strengthening and consolidating after class are the three parts of the teaching process in the online and offline mixed tutorial mode. However, in online and offline mixed teaching, some teachers do not provide self-study materials prior to class and instead ask students to find relevant literature and author information on their own. Because of the big data mode presented by Internet platform information, students will encounter content deviations and misunderstandings in their interpretation of relevant literature materials or author information.

6. Construction of online and offline mixed tutoring mode for film and television literature class

6.1. Improve students' participation in autonomous learning. There are relatively few theoretical knowledge parts in film and television literature courses, and most of the understanding and appreciation methods used are common forms. In this regard, teachers can concentrate on teaching relevant theoretical knowledge according to its application categories. After students understand and master the basic ways of appreciating literary works, the follow-up teaching of literary works will be more targeted. Before class, the teacher's main task is to carefully analyze the learning situation, so as to choose reasonable teaching content and online teaching platform, and put forward certain requirements and effective suggestions for students' online learning content. At the same time, the teacher should make clear the learning objectives, learning priorities and learning difficulties of film and television literature course teaching through micro-class or PPT, so that students can actively, effectively and independently learn, and provide knowledge reserve for offline classroom teaching. Figure 1 is the dimension of effective learning environment of film and television literature and the path analysis model with learning effect.

Before class, teachers construct structured courses by designing curriculum guidance, unit knowledge tree and knowledge branch, setting exercises, discussion and inquiry topics before class, and establishing evaluation system. Teachers can arrange the task of watching movies in advance, so that students can have a preliminary understanding of the movies they want to learn, and set up simulation topics and examples related to movies by using teaching platforms such as rain class or cloud class class, so that students can learn by themselves first. Using modern IT to implement online and offline mixed teaching can not only effectively and rationally use time, but also remind and urge students to study tasks that need to be previewed before each class, and provide students with a broader learning path, thus helping to improve the teaching effect of film and television literature courses.

Teachers should deeply understand and combine students' individual characteristics, carefully select, design and prepare high-quality teaching and learning resources with different online difficulties according to the syllabus and teaching difficulties, so as to facilitate students' graded learning and help them to preliminarily understand and master knowledge content. Figure 2 shows the resource supply relationship of mixed teaching courses in universities.

Students are encouraged to explore and learn independently in class by using high-quality online curriculum resources or teacher-prepared video courses. Teachers use heuristic knowledge topics in class to guide students' independent thinking, discuss knowledge points, explain examples and exercises using the network platform, and analyse and calculate students' feedback questions that have been summarised before class. Simultaneously, combine different knowledge points, select application cases for teaching to enrich classroom content, and set up classroom tasks or group discussions to encourage students to engage in interactive communication, thus enlivening the classroom atmosphere. Students can use the mutual evaluation system set up in class to score and evaluate each other, enhancing students' sense of classroom integration.

6.2. Optimizing teaching process design. Optimizing the design of the teaching process can not only help students to strengthen their understanding of the literature knowledge they have learned, but also promote the teaching effect on the basis of enhancing students' interest in literature. First of all, in the pre-class self-study stage, teachers should give priority to searching and sorting out relevant literature knowledge, and tell students from which aspects to interpret the information of works. Teachers should have a purposeful dialogue between teachers and students in class according to the difficult points of students' feedback before class, and guide students at different levels individually to teach students in accordance with their aptitude. For students with

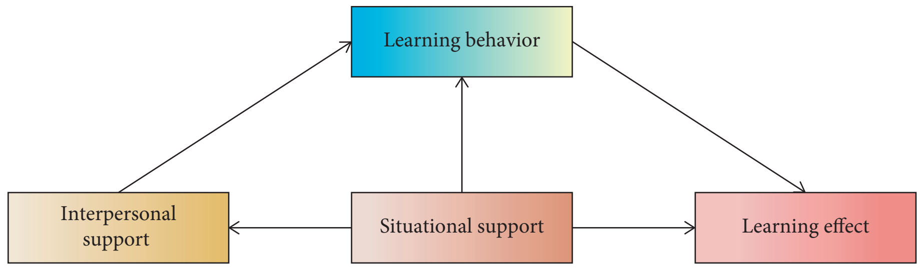

Figure 1: Path analysis model.

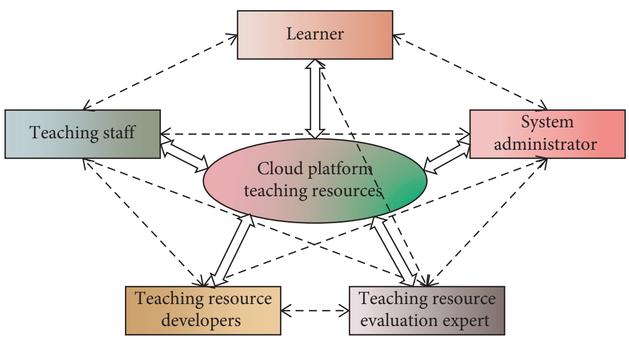

Figure 2: The supply relationship of mixed teaching curriculum resources.

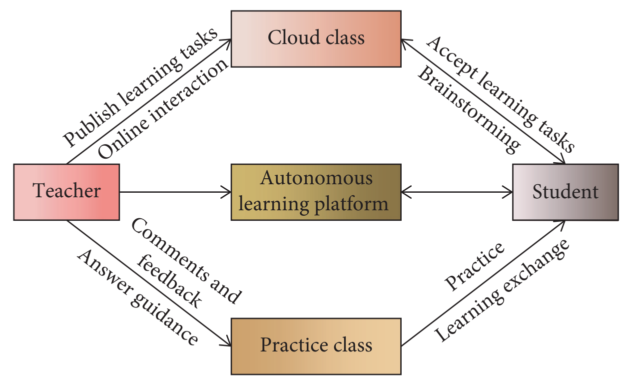

Figure 3: Mixed teaching implementation method.

good foundation and strong learning ability, teachers can assign some difficult learning tasks to expand their knowledge, and for students with poor foundation and weak learning ability, teachers can help them answer questions in class. In the class, teachers can selectively determine the content of lectures according to the movie watching tasks assigned before class, the feedback from the teaching platform to students' preview tasks before class, and the questions and discussions that students have made through the platform. The implementation method of mixed teaching is shown in Figure 3.

One of the great advantages of mixed tutorial mode is that it can provide students with a personalized learning space, so that learners can achieve completely independent personality learning. However, it is not easy to truly reflect this advantage, which requires systematic design of the whole network learning environment. The learning path components are shown in Figure 4.

Because students have a preliminary knowledge and understanding of the film before class, teachers should deepen and guide students' appreciation and understanding of the film in class. At the end of the course, teachers can use the last five minutes of the class to summarize and clarify the key points and difficulties in this class, so that the teaching effect can be guaranteed to the greatest extent. After class, teachers can arrange homework through online learning platform, the content can be about film appreciation or film appreciation, etc., so that students can extend and expand their knowledge about what they have learned about film appreciation. Students consolidate their knowledge and finish their homework, and then give feedback on their homework. After the first stage of listening and speaking teaching of film and television literature supported by mixed teaching method is completed, a stage test is required, and the test results are shown in Figure 5.

Teachers can reflect after class according to students' preview before class and the implementation of teaching in class, and both teachers and students can summarize from the perspective of teaching and learning. Online-offline mixed tutorial mode can enable teachers to adopt the most effective and direct teaching methods, carry out reform and exploration, and further improve students' learning status and teachers' teaching level. For example, Figures 6 and 7 is the survey result of students' satisfaction with online and offline mixed teaching of film and television literature course.

It is clear from Figure 6 and 7 that most students are satisfied with the multi-mixed tutorial mode. In addition to assigning homework of classroom teaching content, teachers can also introduce the frontiers of scientific research and provide practical application cases in combination with teaching knowledge points and teachers' own research direction, so as to help students broaden their horizons, stimulate their interest in learning and deepen their understanding of knowledge. Table 7 shows the statistics of students' evaluation on teachers' use of multimedia courseware in film and television literature teaching.

The premise of mixed tutorial mode is the Internet, which requires teachers to master the application of IT, which is the general trend in the teaching of film and television literature. Teachers should improve their IT level in actual teaching, fully and effectively integrate teaching resources of film and television literature with IT, innovate tutorial mode, change teaching environment and optimize classroom atmosphere. The independent explanatory power

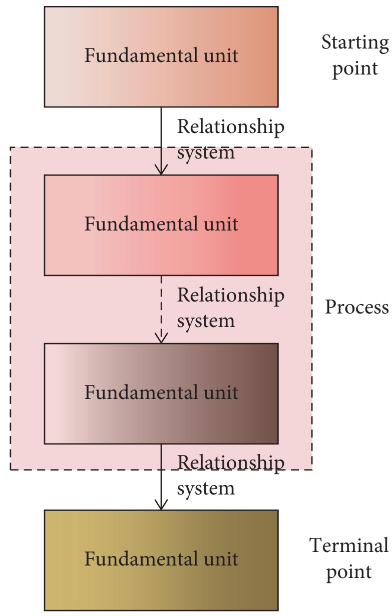

FIGURE 4: Elements of Learning Path.

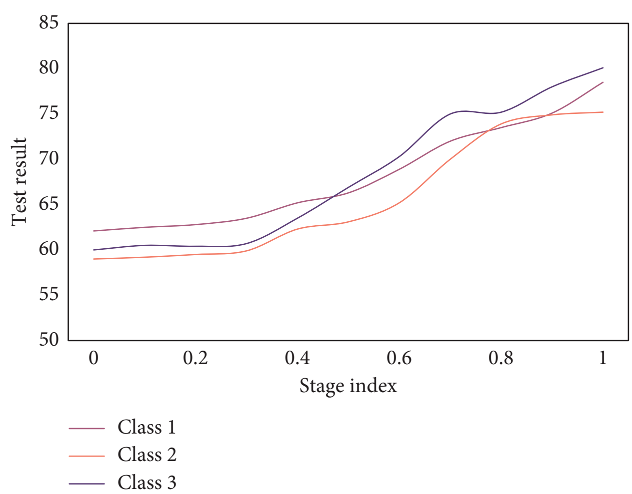

FIGURE 5: Comparison of stage test score data.

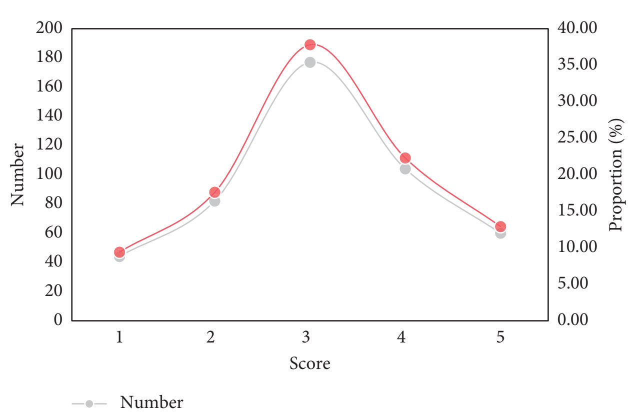

FIGURE 6: Survey statistics of students' satisfaction with online and offline mixed teaching.

data of the three dimensions of effective learning environment shows that both learning behavior and situational support have strong explanatory power to learning effect, as shown in Figure 8.

Most students take part in some exams related to professional skills while studying professional courses. The heavy learning tasks lead to the change of unsuitable teaching methods. Therefore, they have coping psychology for online learning, and can't finish online learning tasks assigned by teachers on time, quality and quantity. Therefore, schools should actively adjust teaching evaluation methods, emphasize the importance of process evaluation, arouse students' attention and attention, and then improve students' learning consciousness and enthusiasm. Students independently or in groups carefully complete the exercises, discussions and feedback after class, and freely put forward

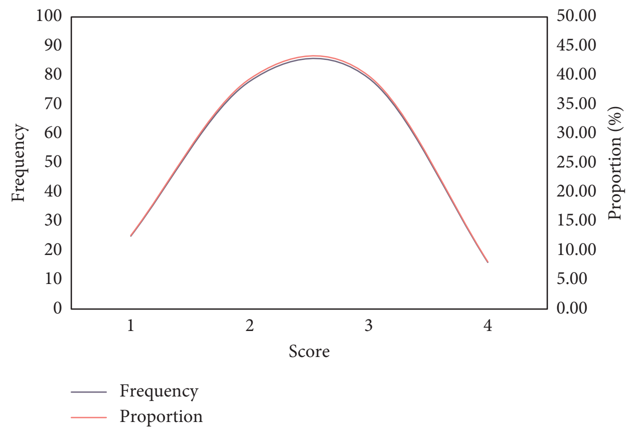

Figure 7: Students' evaluation of the effect of multimedia courseware.

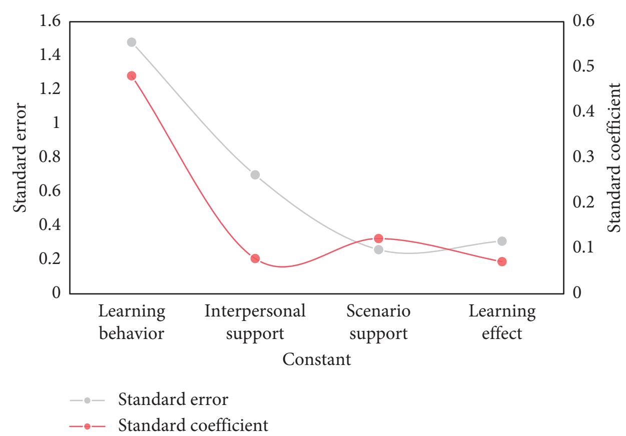

Figure 8: Effective learning environment construction corpus estimated results of learning effect.

their own opinions and suggestions on teaching design, teaching content and teaching videos through the teaching evaluation system, thus forming a good cycle between teachers' teaching and students' learning.

7. Conclusions

Film and television literature courses are different from general cultural courses. Today, with the emphasis on humanistic quality education, the methods and skills of film and television works appreciation can reflect students' thinking mode and aesthetic ability. Today, with the rapid development of the Internet, the film and television literature course is no longer a simple explanation of works and appreciation of contents. Through network information expansion, it can show students a more brilliant side of literary works. Strengthening the teaching of film and television literature works is the need of the development of the times and an important channel to improve students' cultural literacy. The appreciation of film and television literary works will provide a new growing point for the deepening of Chinese teaching reform. Online-offline mixed tutorial mode provides students with rich teaching resources and broad learning space, which enables students to change from passive learning to active learning. Students can watch videos independently before class, complete the preview work, and fully stimulate students' learning enthusiasm, thus contributing to the improvement of classroom teaching quality and teaching effect. With the development of the times, the teaching method based solely on lectures can no longer meet the needs of students. The online and offline mixed tutorial mode can improve the teaching quality, enhance the learning efficiency of students and promote their all-round development.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

A Research of Neural Network Optimization Technology for Apple Freshness Recognition Based on Gas Sensor Array

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In the process of growth, apples' ripening, storage, transportation, and processing, the appearance and internal physiological characteristics will have some changes because of the effect of time and physical attributes. A series of problems, such as the false ripeness and putrefaction of fruit, will bring huge economic losses to fruit vendors and harm to consumers. In this paper, an odor recognition system has been designed for the fast evaluation of the freshness characteristics of apples, which is based on the freshness characteristics of Fuji apple. A series of apple-air mixture with equivalent model was established by studying the change of gas concentration during the growth and storage of apples. The continuous projection algorithm (Successive Projections Algorithm, SPA) is used to optimize the sensor array to solve the problems of collinearity and overlap and also to eliminate the abnormal and redundant sensors. ZigBee wireless sensor network is adopted to send data to host computer, and BP (Error Backpropagation) neural network algorithm optimized by SFLA (shuffled complex evolution, SCE + Particle Swarm Optimization, PSO) algorithm is used to recognize gas data, which greatly improves the training speed and precision of neural network. The experimental results show that the detection accuracy of the Fuji apples freshness is 98.67% and can quickly and comprehensively identify the freshness of apples.

1. Introduction

In 1961 Moncrieff, the first to complete the study of odor recognition technology, developed a mechanical odor detection device. In 1982, Persaud and Dodd proposed the concept of an electronic nose, which consisted of two main components: an odor sensor array and a pattern recognition system. The odor sensor is the core component of the electronic nose system. Because single odor sensor cannot evaluate the complex odor components of objects, the selective chemical sensor array is adopted. At present, the most commonly used sensors are metal oxide semiconductor sensors, metal semiconductor field effect transistor sensors, fast ion conductor sensors, optical odor sensors, and mass sensors. Among these sensors, the MOS (metal oxide semiconductor) sensor based on changes operates in its conductivity and resistance, which are caused by the measured redox between the odor and the odor sensing component. This is the most widely used sensor. Based on the data collected by the sensor array, simple and complex odors can be identified by an appropriate pattern recognition system.

Apple not only has sweet flavor, but also is rich in nutrition, which is a kind of high value fruit. According to the Food and Agriculture Organization of the United Nations, apple production worldwide exceeded 70 million tons in 2019. However, in the process of picking, processing, transportation, and storage, its appearance and internal physiological characteristics will be changed due to the problems of false maturation, mechanical damage, and fungal infection, which will bring huge economic losses. It is an important problem to detect the freshness of apple.

Italy's Natale et al. [1] examined the quality of harvested oranges and apples using odor recognition and found that the method could predict apples' defects. Brezmes et al. [2] used smell recognition to detect the ripeness of pear, apple, and peach, adopted neural network analysis to identify fruit samples, and also found that there is a close relationship between smell signal and fruit; the success rate is up to 92%. Although China starts late in the research of odor recognition technology, it has made great progress. In 1995, Pan and others first developed a system to detect smell of apples. The sensor array is used to collect the gas signal, then extracts the characteristic value from the signal curve, and uses the characteristic value as the input vector of pattern recognition. According to the results of signal processing by PCA (Principal Component Analysis), the good and bad apples can be identified, but there are overlapping parts. The research is mainly carried out under the condition of laboratory, and the classification level and the recognition efficiency need to be further improved. Hu et al. [3] used PEN2 electronic nose system to detect citrus fruits stored in different ways and time. The results showed that linear discriminant method was better than principal component analysis method in identifying citrus fruits stored in different time. The load analysis shows that 2, 7, and 9 sensors have great effect on citrus aroma. Electronic nose is expensive and cannot meet the requirements of large-scale applications. A 2017 study by Guo and Sun [4] found that ethylene release from apples is closely related to their ripeness. When ethylene release is less than $1\,\mathrm{mg} \cdot \mathrm{L}^{-1}$, the apples do not ripen; when ethylene release is greater than $1\,\mathrm{mg} \cdot \mathrm{L}^{-1}$, or less than $6\,\mathrm{mg} \cdot \mathrm{L}^{-1}$, the apples do ripen; when ethylene release is greater than $6\,\mathrm{mg} \cdot \mathrm{L}^{-1}$, the apples overripe. Because of the complex changes of the external environment, the concentration of single gas is not enough to judge the freshness characteristics accurately, but the research results of the concentration characteristics of ethylene gas are of great significance to freshness identification technology.

At present, the study of odor recognition technology in scientific research institutions is still in the laboratory stage, which is suitable for on-the-spot real-time detection and network remote monitoring. The key technologies such as gas sensing mechanism and pattern recognition algorithm still need to be further improved and modified. In this paper, a high-precision identification and matching algorithm is proposed to transmit detection data by wireless communication in the open environment, in which the self-made gas sensor array has a great price advantage over the finished electronic nose.

2. Related Work

2.1. Technical Principle. The odor recognition system consists of two parts: hardware system and software system. The software system is the host computer, mainly the pattern recognition module as well as the signal reprocessing unit. As a key part of converting gas signals into electrical signals, the gas detector has to be sensitive enough to identify and collect the mixture of gases produced by apples. The signal processing circuit preprocesses the signals collected by the sensors, such as filtering, amplifying, A/D conversion, etc. to reduce noise and signal errors. The obtained analog voltage signal is changed into a binary number that can be processed by a computer. The function of the signal reprocessing unit of the upper computer is to convert the binary signals collected by the computer into digital/analog signals and smoothen the signals. Finally, the signal recognition process is performed by the pattern recognition module to realize the quantitative and qualitative analysis of the measured gas. The basic workflow is shown in Figure 1.

As a core component of the odor recognition system, the performance of the gas detector directly determines the function of the odor recognition system. The gas detector is a key bridge for shifting gas signals into electrical signals, and when measuring the gas produced by the apples, the sensor adjusts the gas sample to filter out extraneous interference. The gas detector with good performance indicators can greatly improve the detection sensitivity of odor recognition systems. In an odor recognition system, the gas detector and its arrays must satisfy the following conditions:

(1) Gas detectors are able to identify different odors among the gas mixture, with strong gas detection generality, and also able to identify various odors at the molecular level

(2) When a gas sensor detects a kind of gas, the reaction to the gas odor molecule must be rapid and repeatable, without any "memory effect"

The smell of apples is another important indicator of their freshness. So far, more than 300 volatile compounds have been identified in apples, but only a small number of compounds can characterize the freshness of apples. In order to more accurately identify the changes of mixed gases during the process of apple deterioration, it is necessary for apple odor recognition system to be sensitive to distinguish the changes of different gases. The odor recognition system identifies the apple gas by the chemical reaction between the volatile gas mixture of apples to be measured and the sensitive material of gas sensor. So that the gas sensor generates resistance value, current, and other electrical signal changes to realize the acquisition from nonelectrical gas signal to the electrical signal. The collected electrical signals are transmitted to the host computer system, and after processing the signals, the characteristics of the apple odor signals are extracted. The changes of gas were identified by the system pattern recognition unit, and the results of freshness of apples were compared by the analysis system.

2.2. Technical Methods. Our research team has done a lot of relevant research work on odor recognition technology and completed the related system design, algorithm research, experimental data analysis, and so on. The system consists of host, ZigBee transmitter, ZigBee receiver, airtight box, and sensor array, as shown in Figure 2.

PC computer as the host is used as the controller of the experiment system and the memory of the experiment data, and the display can show the change of the gas concentration during the experiment. The ZigBee sensor array is used to collect gas concentration in the sealed box. The ZigBee transmitter sends gas concentration collected by sensor array to the ZigBee receiver; the computer processes the data and identifies the freshness. The system uses wireless sensor network nodes to realize data transmission. The use of wireless transmission technology increases the universality

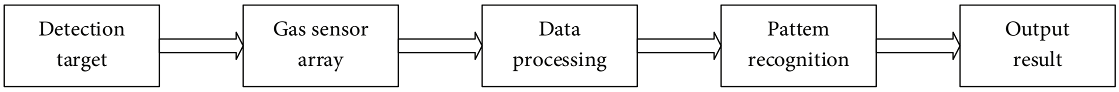


Figure 1: Odor recognition system flow.

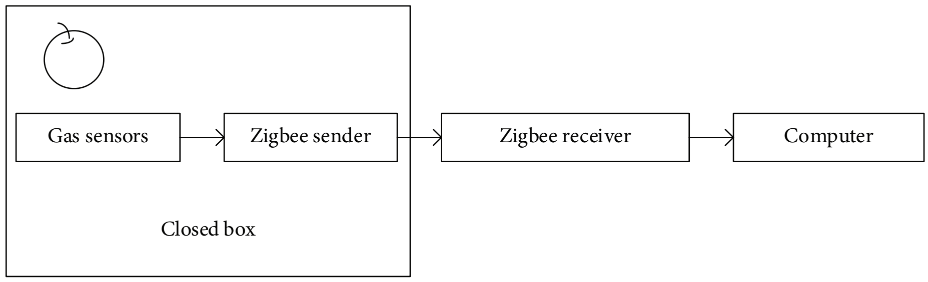


Figure 2: Composition of odor recognition system.

and convenience of the system. The airtight box has conductor grounding, used for shielding outside electromagnetic wave.

The types of sensors and performance indicators are shown in Table 1.

Because performance of gas sensor is affected by temperature and humidity, the experiment is carried out under the condition that the temperature and humidity are relatively stable. The gas collection steps are as follows:

(1) Put the gas sensor collection array into the sealed box, power up, and preheat

(2) The apple sample is placed in an airtight box, the gas is evenly diffused, and the smell emitted by apple to be measured reacts with the sensor array in the airtight box to produce an electric signal, and the data is collected and stored in the PC by ZigBee transmitter and receiver

(3) Preprocess the collected data and repeat the steps above by introducing clean air to restore the sensor to its original state after each measurement

For apples of different freshness, final response signal size is different. The CO2 concentration is measured among fresh, not-fresh, rotten, and severely rotten apples as shown in Figure 3.

From the graph, the concentration of carbon dioxide in apples increases with time, reaching a certain value, and freshness of apples is directly related to the concentration of carbon dioxide. Ranging from fresh, not stale, rotten to severely decayed, CO2 concentration is getting higher and higher. Other gases are collected and treated in a manner similar to carbon dioxide. In different test environments, the single gas concentration does not have unique identification characteristics, so it is necessary to collect data from other gas sensors and fuse the data to judge the freshness of apple.

2.3. Experimental and Data Processing Techniques. Sixteen apples were measured and the training data were normalized. According to the fresh characteristics of apples, the expected output vector of fresh apples is set as [1, 0, 0, 0]; the expected output vector of not-fresh apples is set as [0, 1, 0, 0]; and the expected output vector of rotten apples is set as [0,0,1,0]. The 16 apple charts are shown in Figure 4.

The original data collected by the sensor cannot be used directly for training and recognition because of great noise caused by the interference of the system itself and the external electromagnetic wave. Data preprocessing noise is used to extract the eigenvalue of the signals collected by the sensor array.

Firstly, the data collected by the sensor array are preprocessed, secondly, the eigenvalues are selected, and finally, BP neural network is used to identify the data. The construction of BP neural network determines the structure of BP neural network based on the characteristics of input and output data of the system. Because the input signal of gas eigenvalues has 15 dimensions and 3 types of apple fruit surface features are classified, the structure of BP neural network is 15-9-3. The training process of BP neural network includes the following steps:

(1) Network initialization

(2) Hidden layer output calculation

(3) Output computing in the output layer

(4) Error calculation

(5) Weight update

(6) Threshold update

(7) Determine whether the algorithm iteration is over, and if not, return to the hidden layer to output the calculation steps

In the process of identifying 16 groups of apples, recognition rate of apples can reach 93.75%, which shows that it is more accurate to identify degree of freshness of apples by using odor recognition combined with the ordinary matrix multiplication method in fuzzy comprehensive evaluation and can effectively identify degree of freshness of apples and categories. The identification result of number 11 in the experimental results is inconsistent with the actual freshness of apples. Due to data error caused by influence of external noise in the course of data collecting, the freshness of some apples cannot be correctly identified.

Table 1: Gas sensor array.

No.	Sensor model	Measured gas	Measuring range	Working voltage (V)
S1	MQ3	Ethanol	25–500 ppm	5.0
S2	MG811	Carbon dioxide	0–10000 ppm	6
S3	ME2-O2	Oxygen	0–25% vol	3.3
S4	ME3-C2H4	Ethylene	0–100 ppm	5.0

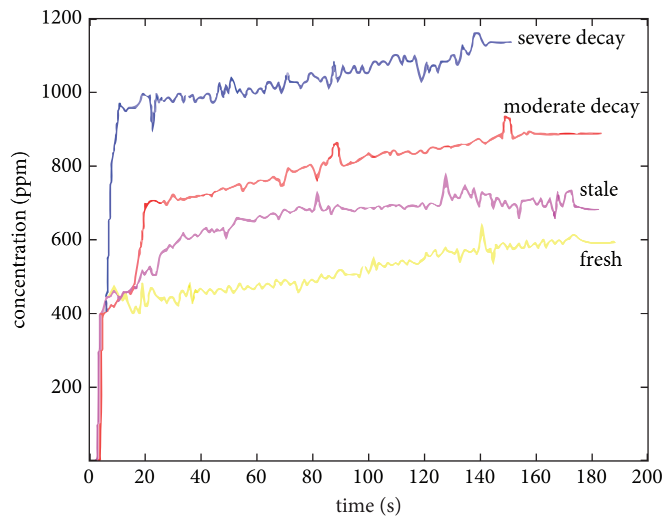


Figure 3: Curve of carbon dioxide concentration with different freshness on fruit surface.

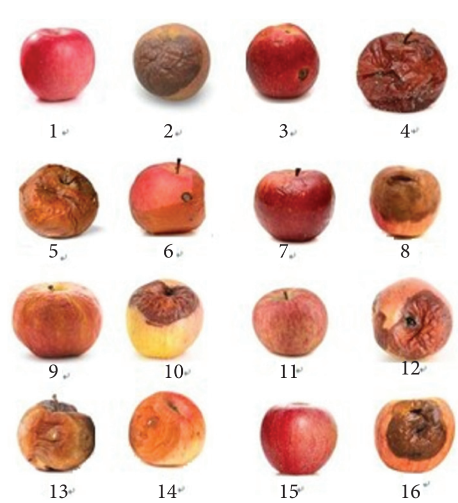


Figure 4: Sixteen Fuji apples.

3. Fast Freshness Identification Technology

At present, the experimental method and algorithm research are mainly carried out in the laboratory condition, and gas concentration collection method in the closed environment, using the traditional BP neural network recognition technology, has the good effect. Therefore, feasibility of the odor recognition technology in the identification of apple freshness is verified. However, in the current information acquisition process, with the process of exhaust, sensor preheating, and acquisition information stability, the more complicated the procedure is, the longer the detection time is. The technology is still lacking field practicality. It is hoped that apple freshness can be identified quickly and related work such as experiment method, sensor array optimization, and algorithm optimization can be carried out on the basis of the research.

3.1. Experimental Apparatus. A gas sensor array is placed in a test vessel in a small container, put one apple at each time, and the gas emitted from the apple is detected at room temperature of 20°C and humidity of 50% Rh. The experimental equipment is shown in Figures 5 and 6. The odor recognition system is used to detect and analyze apples with different freshness.

A preheated sensor array is used to detect change of gas concentration in the process of apple aroma emission. In Figure 5, a battery powered wireless transmission module and a gas sensor array integrated circuit board are attached to the top of the glass bottle to capture apple smell. A wireless sending node is integrated into the circuit board of the sensor array, the apple test sample is placed on the test-bed, and the test bottle clasp after the sensor prediction is placed over the sample to collect all kinds of gases emitted by the sample. Figure 6 is another ZigBee wireless transmission node connected to the host computer, which receives the gas concentration data collected by the gas sensor array and saves it to the PC.

The steps are as follows:

(1) Establish a data acquisition platform and wireless transmission ZigBee network

(2) Preheat sensor array for 5 min according to the requirements of the sensor, and observe the data of the sensor collected by PC through serial port until it becomes stable, and then start the sample detection

(3) 300 groups of fresh, moderately rotten, and severely rotten apples are placed in the test box for 5 minutes in sequence, and the residual gases in the test box are removed by headspace method or drainage method between samples to ensure the consistency of the test environment and the accuracy of the sample data

(4) The collected 900 sets of data are classified and saved according to different freshness characteristics

3.2. Data Acquisition and Preprocessing. Among the odor recognition sensor arrays, the ethylene gas sensor is a ME3-C2H4 galvanic cell type sensor with an output current proportional to concentration, but a maximum output current is only 140 UA and a load voltage is 100 ohms, so it is necessary to enlarge original signal and control its output voltage in 0–3.3 V for follow-up processing. The ethylene concentration calculation formula is shown in the following formula in PPM.

$$P = \frac{83}{(2.207 - 0.608) * \left(V_{\text{out}} - 0.608\right)}. \quad (1)$$

In the open environment, the concentration of carbon dioxide, ethylene, ethanol, and oxygen in three kinds of apples is measured by gas identification system. Figure 7 shows the experimental results.

The original data collected by the sensor cannot be directly used for training and recognition because of interference of system itself, temperature sensitivity of sensor, and even interference of external electromagnetic wave. The data preprocessing process is to preprocess sensor array signal to extract eigenvalues. The process is as follows.

3.2.1. Data for Removing Singularities. The data of carbon dioxide, ethylene, ethanol, and oxygen concentration are obtained by eliminating singularity of original data of apples with different freshness.

3.2.2. Least Square Filtering. Because of interference of the system and temperature sensitivity of the sensor, the data are filtered by linear least square filter to remove noise and get a relatively smooth image.

3.2.3. Extraction of Eigenvalues. Take the first 60 seconds and every 5 seconds to take a data eigenvalue, multipoint eigenvalue extraction to do data training, then take the data filter processing. The results are shown in Figure 8.

As can be seen from the diagram, after preprocessing, concentration information of carbon dioxide, ethanol, and ethylene after 30 seconds is used as determining factor to determine freshness of apple based on stability of the sensor. The extracted data are trained and tested by extracting the eigenvalues.

The original data volume of gas sensor array is very large, dimension is correspondingly large, so complexity of classifier is also increasing; and it is easy to produce explosion. The performance of classifier can be improved by reducing dimension and improving extraction of eigenvalues. The extraction of sensor data eigenvalues is to transform the samples from high-dimensional space to low-dimensional space by mapping or transformation and extract main information which reflects essential attributes of target signal. The optimal value of BP neural network optimized by hybrid frog-leaping algorithm is used to train the network, which can accurately distinguish apples with different freshness.

3.3. Optimization of Sensor Array. In the process of odor recognition, sensor array is the key of information collection. Using reasonable gas sensor can not only improve recognition accuracy, but also improve collection efficiency. Continuous projection algorithm (SPA) is a forward variable selection method, which is used to solve classification problem. The purpose of SPA is to select a small set of variables with less redundancy and minimum collinearity, with elimination of redundant information in original matrix. The correlation contribution of each sensor to different freshness of apple is studied by PCA analysis. Figure 9 is a bar chart of the contribution rates. Figure 10 is a histogram comparison of RMSEP (Root-Mean-Square Error of Prediction).

As can be seen from the diagram, values of all sensors on PC1 are greater than 0.8, and the load coefficients of S2, S3, and S4 are very close, which means that these sensors have similar recognition functions and some overlapping information. Therefore, redundant sensors can be removed from the array. By retaining useful sensors and eliminating redundant ones, the sensor array platform of the system is reconfigured by using sensor array optimization SPA algorithm. Figure 10 shows RMSEP with different number of variables (number of sensors), in which three sensors (S1, S2, and S4) in the array are selected according to the relatively low RMSEP.

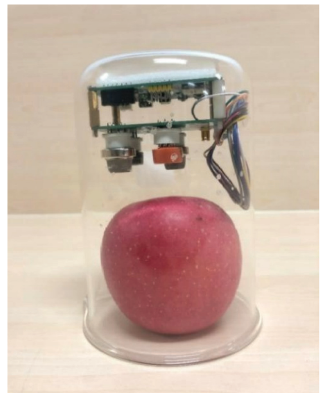


Figure 5: Physical diagram of data acquisition.

Figure 6: PC wireless transmission and reception node.

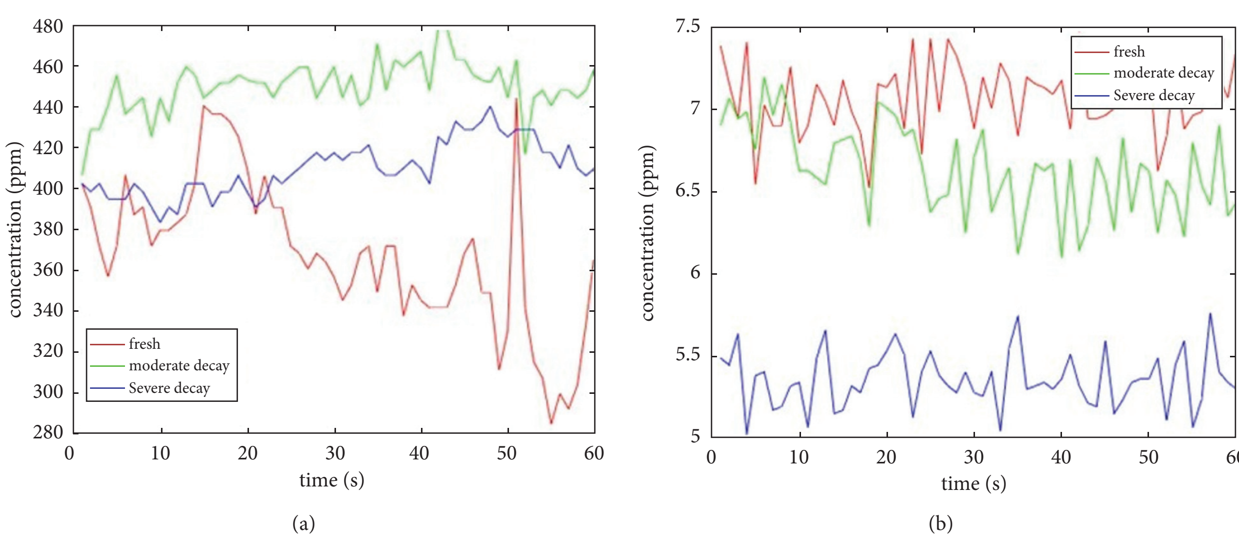
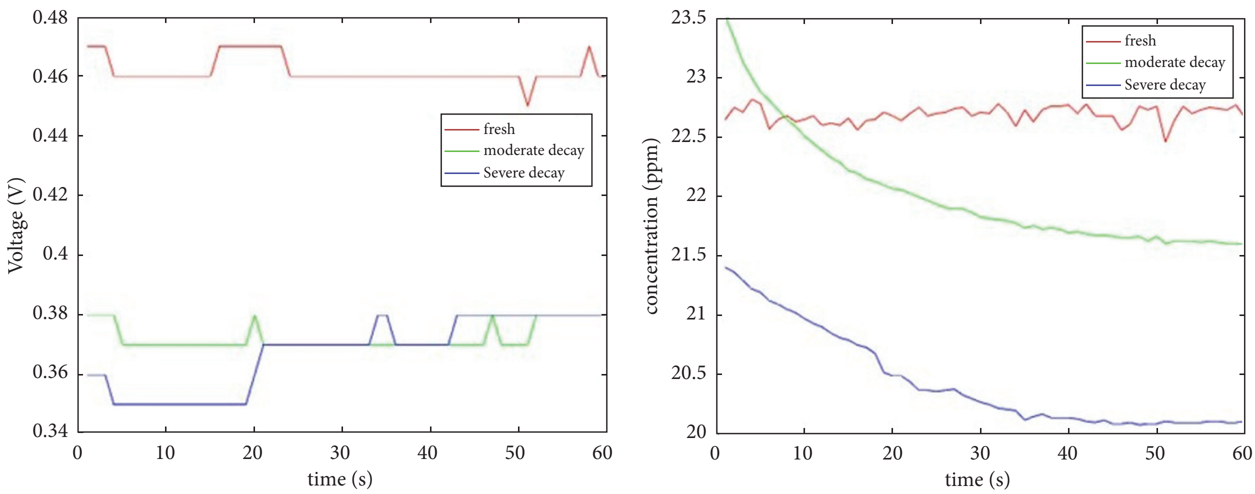
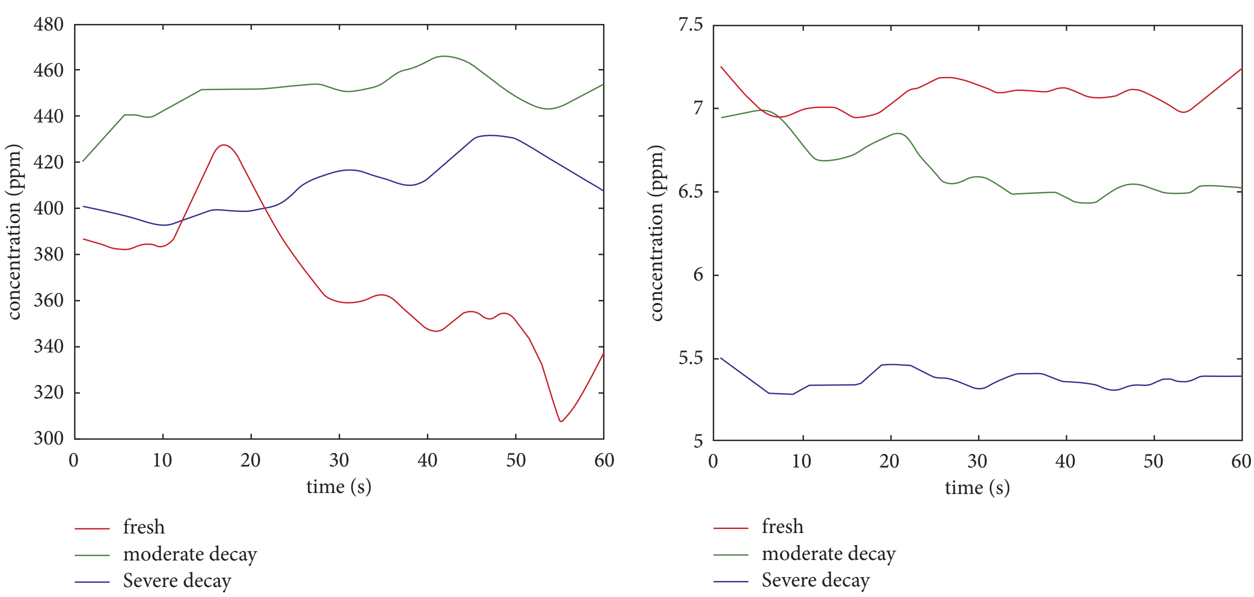


Figure 7: Continued.



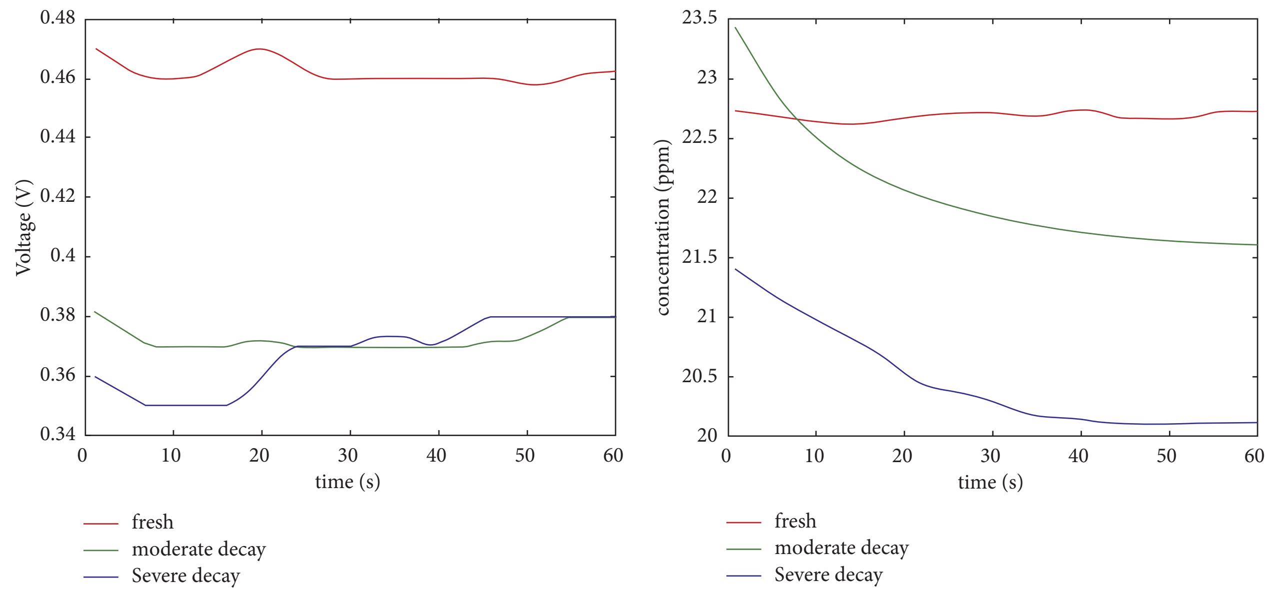
(c) (d)

Figure 7: 60S apple gas concentration contrast. (a) Carbon dioxide concentration. (b) Ethylene concentration. (c) Ethanol concentration. (d) Oxygen concentration.



(a) (b)

Figure 8: Continued.



(c) (d)

FIGURE 8: 60s filter apple gas concentration contrast. (a) Carbon dioxide concentration. (b) Ethylene concentration contrast. (c) Ethanol concentration. (d) Oxygen concentration.

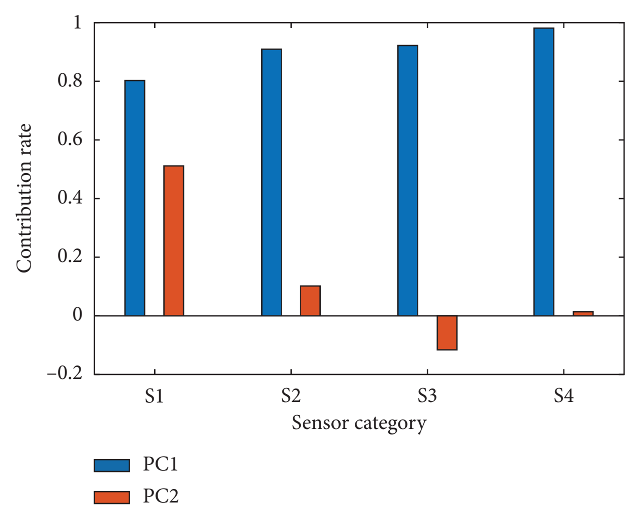


FIGURE 9: Sensor contribution load diagram in first two principal component analyses.

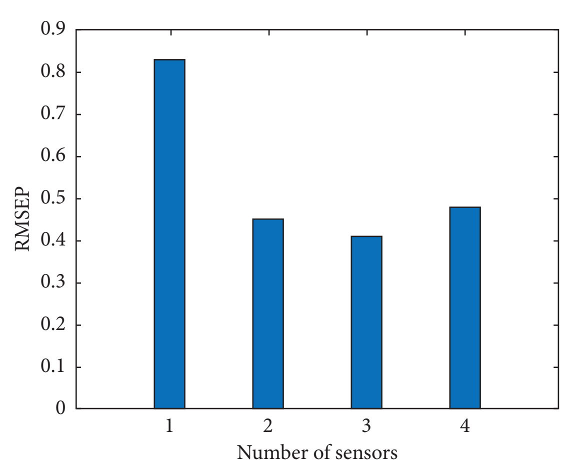


FIGURE 10: RMSEP values for different variables.

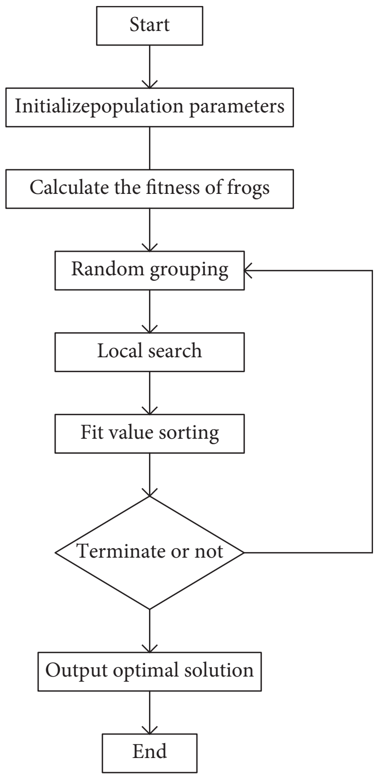


Figure 11: Flowchart of mixed leapfrog algorithm.

3.4. Hybrid Leapfrog Algorithm. Leapfrog algorithm (SFLA) is a heuristic group evolutionary algorithm with high computational performance and excellent global search ability. The flow of hybrid leapfrog algorithm is shown in Figure 11.

The algorithm works like this:

(1) Initialize the population information to determine the population size F, as shown in the following formula:

$$\mathrm{F} = \mathrm{m} * n. \quad (2)$$

Among them, m is for the number of subgroups, and n is for the number of frogs in each group.

(2) Compute fitness, the objective function value for each solution.

(3) According to descending order of fitness, write down location of the first best frog as the first global optimal solution. F frogs are assigned to m groups and each group has n frogs. Then start population optimization (local optimization). The positions of the best and worst frogs in the subpopulations are recorded as P_b and P_W, respectively. Trigonometric probability distribution is used to assign more weights to frogs with better fitness values and lower weights to frogs with worse fitness values. So the highest probability of a frog being selected as a subgroup is $P_1 = 2/(n+1)$, and the lowest probability is $P_1 = 2/n(n+1)$. Update position of the frog by optimizing the position of the worst frog in the subgroup in formulas (3) and (4).

$$D_S = \mathrm{rand}() * (P_b - P_W), \quad (3)$$

rand() is a random number of [0, 1].

$$\begin{aligned} D_S &= \min\{\mathrm{int}[\mathrm{rand}() * (P_b - P_W)], S_{\max}\} \\ &= \max\{\mathrm{int}[\mathrm{rand}() * (P_b - P_W)], -S_{\max}\}, \end{aligned} \quad (4)$$

$(-D_{\max} \le D_S \le D_{\max}) S_{\max}$ represents the maximum step allowed by an individual frog.

Replace the bad frog with the better frog, and if you do not get a better frog after the update, randomly generate a frog to replace P_W and return to the loop. The algorithm outputs the optimal solution and ends until the number of cycles or the stop condition is met.

3.5. Optimizing BP Neural Network. The structure of BP neural network is determined according to characteristics of input and output data of the system. Because the input signals of odor characteristics have 9 dimensions, there are 3 kinds of freshness characteristics to be classified. According to Kolmogorov's theorem, the range of hidden layer nodes is [4, 13], and the optimum number of hidden layers n is 10. So the structure of BP neural network is 9-10-3; that is, there are 9 nodes in input layer and 10 nodes in hidden layer; the output layer has three nodes.

After pretreatment, 900 groups of fresh degree characteristic signals are selected, from which 750 groups of data are randomly selected to train the network, and 150 groups of data are used to test the network classification ability. The expected output vector of fresh apple is set to [1, 0, 0]; the expected output vector of moderately rotten apple is set to [0, 1, 0]; the expected output vector of severely rotten apple is set to [0, 0, 1]. The training data are normalized according to the following formula:

$$X_n = \frac{x_n - x_{\min}}{x_{\max} - x_{\min}}. \quad (5)$$

The training error of BP neural network is shown in Figure 12, and the training error of optimized network is shown in Figure 13.

The unoptimized network reaches the minimum system error $4.21e^{-12}$ after 15 iterations, and the optimized network reaches the minimum system error $3.49e^{-10}$ after 12 iterations. The optimized network has fewer iterations than the unoptimized network, and the optimized algorithm is better than the original algorithm in training times and error.

Through 750 sets of data trained network, 150 sets of data are classified and 150 sets of sample data are randomly mixed to test accuracy and stability of the network. The results show that freshness of apples is divided into three grades; 148 out of 150 groups of test data could correctly identify the freshness of apple, and the classification accuracy is as high as 98.67%.

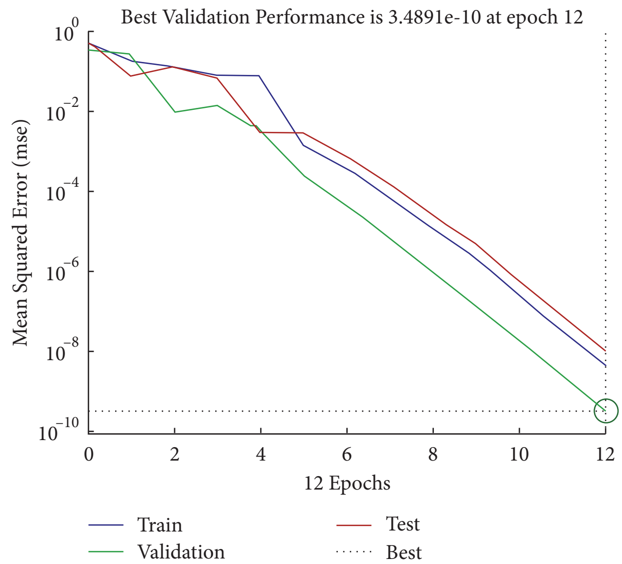


Figure 12: BP training error.

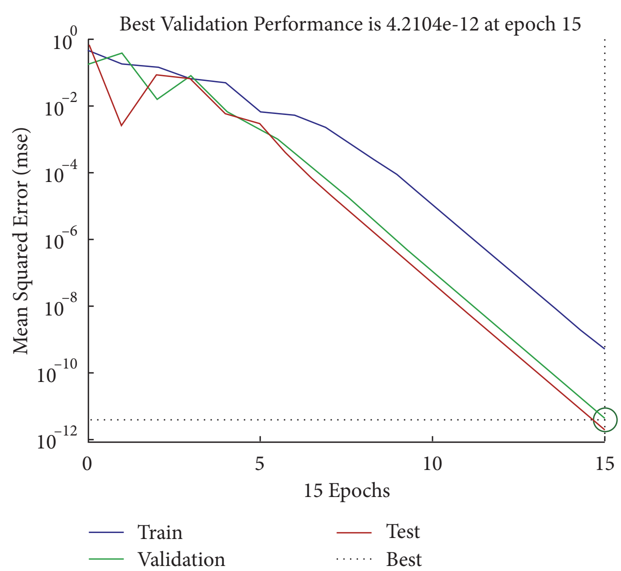


Figure 13: Optimizing BP training error.

4. Conclusion

In this paper, quick detection and analysis of apple freshness is completed by the optimization of odor recognition system, data preprocessing, sensor array, and BP neural network algorithm optimized by mixed frog leaping. The experimental results show that the algorithm has advantages of strong overall searching ability, fast training speed, and high recognition efficiency. The sensor array has reasonable composition and high accuracy and also can distinguish apples with different freshness. However, there are some limitations in the application of the system. To identify freshness of different kinds of fruits, it is necessary to pass a large number of experimental data, and the experimental testing time is slightly longer, and further optimization design is needed to realize the fast freshness detection of different kinds of fruits.

Data Availability

Access to data is restricted.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

An Analysis of English Schooling at College Quality Based on Modern Information Technology

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The importance of learning English is increasing as China's foreign exchanges become more frequent. China's independent colleges have been steadily growing in recent years, with the main school's main characteristic of cultivating applied talents, and teaching quality gradually improving. College English teaching is a practical application of college English education and instruction. The "sum of beliefs, recognized values, and technologies commonly accepted by the members of a specific community" is the world outlook and mode of behavior that a group of researchers engaged in a particular science adopts. Modern information technology has pervaded people's work and lives since the dawn of the information age, and it is now widely used in a variety of fields. Teachers' primary roles have shifted from disseminator of information, presenter of knowledge, transmitter of culture, and provider of correct answers in today's learning environment supported by modern information technology to promoter of learning, organizer of activities, student helper, and interactive collaborator. This paper obtains some information useful to the development of teaching work based on the data mining algorithm used in the mining practice of the educational administration information management system. This information is useful for improving teaching quality, implementing the talent development program more effectively, mastering student skill development, and teachers' teaching situations.

1. Introduction

With the increasingly frequent foreign exchanges in China, the importance of English learning is becoming more and more prominent. In recent years, China's independent colleges have developed continuously, with the main school running characteristics of cultivating applied talents, and the schooling quality has been gradually improved [1]. Since the 1990s, English schooling at college units in many Chinese universities have successively launched the schooling quality assurance system. Its main purpose is to improve schooling measures and promote the improvement of schooling quality through continuous schooling quality monitoring. English schooling at college is a specific application in the field of English schooling at college education and schooling [2]. In addition, teachers in independent colleges and universities have many courses and great teaching pressure. Many teachers do not have much energy to design an interesting, interactive and diverse English class. In addition, students are not easy to learn. As a result, many teachers teach according to the book, the teaching form is single, the content is boring, and cramming teaching, which finally make teachers become "lonely speakers" who entertain themselves on the podium.The world outlook and behavior mode that researchers engaged in a certain science follow together is "the sum of beliefs, recognized values and technologies accepted by members of a specific community" [3]. First, the data set is divided into training data set and test data set. First, the training data set is used to construct the model by analyzing the database tuples described by attributes. This stage is also a learning stage. The generated model is expressed in the form of classification rules, mathematical formulas, or decision trees. However, there are still many problems in English schooling at college in independent colleges: students' weak foundation, incorrect learning attitude, poor autonomous learning ability, serious shortage of teachers, unreasonable teacher structure, old and boring schooling mode, serious shortage of schooling hardware, and so on. The evaluation index of schooling quality is an important basis of schooling quality assurance system. The existing evaluation indicators mostly adopt the comprehensive evaluation method, and its index system is usually composed of multilevel indicators [4, 5].

Schools, as the output platform of future talents, should have this forward-looking vision as the universal development of modern information technology marks the rise of global economic integration, closer multilateral cooperation among countries, and continuous improvement of international exchanges. Traditional schooling activities usually only involve teachers, students, schooling materials, and other basic elements, but modern schooling also includes the element of "modern information technology" [6, 7]. This method of assessing educational quality is widely used and has produced some results. Traditional methods of evaluating educational quality, on the other hand, are not without flaws. Teachers' primary roles in the learning environment supported by modern information technology have shifted from information disseminators, presenters of knowledge, transmitters of culture, and providers of correct answers to promoters of learning, organizers of activities, student helpers, and interactive collaborators [8, 9]. This paper uses modern information technology to examine the educational quality of English schooling at the college level in order to serve as a model for future large-scale English schooling implementation at the college level. It is not only possible but also necessary to use modern information technology to assist English schooling in college, and it is an unavoidable requirement for developing innovative talents. English as a language subject has gotten a lot of attention in the process of using modern information technology to innovate traditional education [10, 11] because of its unique communication and practicality.

Assisted by modern information technology, higher vocational schooling can add advantages to traditional schooling, such as strong interaction, large amount of information, strong real-time, diverse media, and rich forms, which have a great positive impact on language learners' mastery of listening, speaking, reading, writing, and translation in English schooling at college and the cultivation of autonomous learning ability, At the same time, English schooling at college reform and English teachers are facing new challenges and opportunities [12]. In order to comprehensively, objectively, scientifically, and accurately evaluate the quality of English schooling at college based on modern information technology, the combination of formative evaluation and summative evaluation should be adopted, and the evaluation procedure should be standardized to ensure the reliability and validity of the evaluation [13]. Students cannot understand the charm of English, cannot have interest in English schooling at college quality, and cannot improve their English level. The data of teachers' teaching evaluation cover a wide range and has qualitative attributes, such as students' overall evaluation. There are also some quantitative attributes, which are relatively few, such as students' evaluation of teachers' teaching content. Data mining algorithm has good efficiency and effect in dealing with discrete data. Before data mining, data can be discretized in advance. Of course, data mining algorithm can also deal with continuous data. Teachers can carefully design and organize schooling through schooling software and network resources to truly play the leading role of teachers [14]. Different from audiovisual schooling means, the application of modern information technology characterized by multimedia and network requires teachers not only to master information application technology, such as word processing and operation skills, but also to learn to use some corresponding schooling software. Modern information technology assisted English schooling at college is a schooling method to cultivate students' comprehensive ability [1]. On the other hand, although multimedia schooling has changed in schooling form, it cannot be separated from the role of teachers' guidance.

2. Related Work

According to literature [15], when English schooling at college goes global, it will be localized, and localization of English schooling at college is an unavoidable result of globalization. According to literature [16] literature, the number of college students in China has risen sharply as a result of the continuous expansion of university enrollment, but English teachers are becoming increasingly tense, which has led to the continuous expansion of class size, with some colleges and universities having more than 100 students in a class. This will inevitably result in fewer language communication activities between teachers and students, resulting in a continued decline in schooling efficiency and quality in English classrooms. Data mining has been facing the application field of solving practical problems since it was proposed, according to literature [17], and its scope is very broad, involving almost all economic and social industries, including economic management, finance, insurance, electric power, astronomy, petrochemical, biology, geography, geology, and so on. According to literature [18], traditional English schooling at college is facing severe challenges due to the application of computer network technology and the development of English network resources. According to literature [19], it can be seen that the development of society promotes homogeneity on the one hand, and the school education theory and its elements are interconnected and further strengthened; on the other hand, the strengthening of localized knowledge and research makes foreign language education present heterogeneity and diversity, which is the interaction of globalization and localization of English education in the university paradigm. Literature [13] research shows that students' English learning materials are very rich, and their learning methods are increasingly diversified. Various English learning websites, audio materials, and multimedia software emerge one after another. Many English schooling at college textbooks are also equipped with CD-ROMs, such as new English schooling at college and new practical English. Literature [20] puts forward that from the perspective of the law of language schooling itself, each country and region has its own unique "localized" language schooling policy, schooling path, schooling approach and schooling method, and has its own unique local culture, language habits, thinking mode and the "migration" interference of mother tongue. Literature [21] through the big data analysis method, as a kind of human cognitive practice, school education activities have a complex interactive relationship among teachers, students, and content. Compared with "school education," teachers are the undertaker and subject of activities, and students are the object and object of teachers' work. Literature [22] studies show that in the face of the wave of globalization, especially the convergence of educational technology development, educational exchanges between the East and the West are also deepening. The globalization trend of foreign language schooling has become inevitable, which is mainly reflected in the diffusion and integration of schooling theories, the international sharing of educational resources, and the development of English schooling at college materials and schooling resources towards a more international trend. Literature [23] pointed out that the application and popularization of network technology are making China form a brand new network society. People's working methods and learning environment have undergone great changes, and it is entirely possible to realize "lifelong education" and "national learning."

Based on the data mining algorithm in modern information technology, this paper analyzes the quality of college English teaching, designs learning tasks, mobilizes learners' potential, provides scaffolding activities for learners, carries out data mining for learners, and gives guidance, feedback, and evaluation on the problems encountered in the learning process.

3. Construction of Algorithm Model for English Schooling at College Quality Analysis

3.1. Data Mining Principle and Algorithm. The data mining algorithm is a global and parallel search optimization algorithm. Students are the initiator and subject of activities, whereas schooling content is the object and object of activities, as opposed to "learning." The following are some of the meanings of this definition: Massive, real-time, and noisy data sources are required; what they uncover is knowledge that is relevant and interesting to users. And the knowledge that is discovered must be understandable, acceptable, and useable; finding universal knowledge is not required, but only supporting specific problems is. When solving optimization problems, data mining algorithms have the problem of searching for the best solution slowly, which is frequently accompanied by premature convergence. According to the advantages of randomness and stable tendency of cloud droplets in cloud model, conditional cloud generation algorithm and basic cloud generation algorithm are adopted to realize crossover and mutation operations, accelerate the search ability, keep the random search, and adaptively adjust the crossover and mutation probability to prevent falling into local optimum defects. The data mining algorithm adopts B/S structure (browser/server, browser/server mode), the server side stores applications and related databases, and customers access the server through the browser. The flow structure of data mining algorithm is shown in Figure 1.

For training sample set $\{(x_i, y_i)\}$, $i = 1, 2, \ldots, n$, $x_i \in R^n$, $y_i \in R$. Xi and Yi are the evaluation index of classroom schooling quality and the output value of classroom schooling quality respectively, which are fitted by the following formula

$$y = \omega^T \cdot x + b, \tag{1}$$

where ω is the weight vector and B is the offset.

According to the principle of structural risk minimization, the SVM regression model for solving the problem of (2) is

$$\min \frac{1}{2}\omega^T \omega + C \sum_{i=1}^{n} (\xi_i + \xi_i^*). \tag{2}$$

Constraints are

$$\begin{cases} y_i - \omega^T \cdot x_i - b \le \varepsilon + \xi_i, \\ \omega^T \cdot x_i + b - y_i \le \varepsilon + \xi_i^*, \\ \xi_i^* \ge 0, \xi_i \ge 0, \end{cases} \tag{3}$$

where c is the penalty parameter and ε is the fitting accuracy between the actual value and the regression function. Using duality theory, the (3) is transformed into a quadratic programming problem, namely

$$\begin{aligned} L(\omega, b, \xi, \alpha) &= \frac{1}{2}\omega^T \omega + C \sum_{i=1}^{n} (\xi_i + \xi_i^*) \\ &\quad + \sum_{i=1}^{n} \alpha_i \left(\omega^T \phi(x_i) - b + \xi_i - y_i\right), \end{aligned} \tag{4}$$

where α_i is Lagranse multiplier.

For the nonlinear classroom schooling quality evaluation problem, the classroom schooling quality training samples are mapped to the high-dimensional feature space through the nonlinear mapping function $\phi(\cdot)$, and the linear regression is carried out. The nonlinear SVR model is

$$y = \sum_{i=1}^{n} (\alpha_i^{\bullet} - \alpha_i) K(x_i, x) + b, \tag{5}$$

where K $(Xi,\ x)$ represents the kernel function.

Let Xi, $XJ \in u$ be described as $Xi = \{Xi, 1, Xi, 2, \ldots, Xi, m\}$, $XJ = \{XJ, 1, XJ, 2, \ldots, XJ, m\}$, then the difference measurement formula for simple matching between Xi and XJ is

$$d\left(x_i, x_j\right) = \sum_{l=1}^{m} \delta\left(x_{i,l}, x_{j,l}\right). \tag{6}$$

Among

$$\delta\left(x_{i,l}, x_{j,l}\right) = \begin{cases} 1, & x_{j,l} \ne x_{i,l}, \\ 0, & x_{j,l} = x_{i,l}. \end{cases} \tag{7}$$

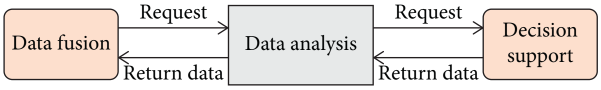

Figure 1: Flow chart of data mining algorithm.

Let $X = \{X1, X2,...,Xn\}$ be a group of data objects, where $X = (xi1, xi2,...,xim)$ represents a data object with m attribute values. Use "mode" to represent this set of data objects, and the mode of x is defined as $Q = (q_1, q_2, \ldots, q_m) \in U$ so that

$$D(X,Q) = \sum_{i=1}^{n} d(X_i, Q). \quad (8)$$

Get the minimum.

Data mining is a method that evolves over time. Data mining, on the other hand, is discovery-driven in that patterns are automatically extracted from data through a lot of searching work. Traditional data analysis methods generally give a hypothesis first and then pass the data verification, which is hypothesis-driven in a sense.

3.2. Analysis Model of English Schooling at College Quality Based on Data Mining Algorithm. Many studies have found that when solving a data mining algorithm, the speed of finding the best solution is slow, and that this is frequently accompanied by premature convergence. The conditional cloud generation algorithm and the basic data mining algorithm are used to realize crossover and mutation operations, accelerate optimization ability, and maintain the randomness of search, according to the randomness and stability tendency of the data mining algorithm. The crossover and mutation probabilities are adaptively adjusted to avoid falling into the defect of local optimization. Educational data mining and learning analysis are the two main directions of big data research in the field of education. Because many independent colleges and universities use the final English score and English schooling at College-4 pass rate of each semester to measure teachers' schooling level, most teachers focus on how to improve students' English schooling at College-4 pass rate and examination pass rate, ignoring English schooling itself. The relationship between educational data mining, learning analysis, and English schooling at college, pedagogy, and schooling quality is shown in Figure 2.

Data mining is an important means of data utilization under the background of big data, which refers to the process of extracting effective, novel, and potentially useful data from a large number of data and utilizing understandable knowledge, models and rules. The data mining algorithm is used to optimize the English schooling at College quality analysis model, and the optimization process is shown in Figure 3.

① Select the evaluation index of English classroom schooling quality.

② Collect the historical data of English classroom schooling quality evaluation, process the data, and eliminate some useless data.

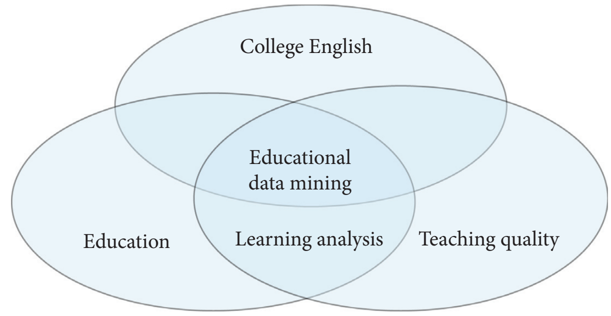

Figure 2: Major disciplines involved in data mining and schooling quality analysis of English schooling at College.

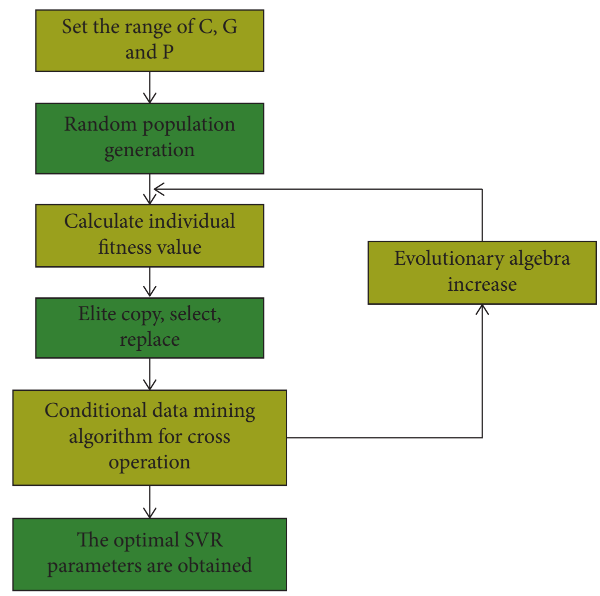

Figure 3: Optimization of English schooling at College quality analysis model based on data mining algorithm.

③ In order to speed up the learning of SVR, the evaluation index values of English schooling at College quality are normalized. The specific normalization formula is as follows:

$$x_i' = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}}, \quad (9)$$

where $x_{\max}$ and $x_{\min}$ represent the maximum and minimum values of each evaluation index, Xi and x'i. Represent the values before and after normalization, respectively.

After processing the data by formula, the range of all indicators is [0,1], which can improve the efficiency of the English schooling at College quality analysis model.

④ Divide the processed and normalized data into two parts: training sample set and test sample set. Input the training samples into SVR for training. In the training process, use data mining algorithm to optimize the English schooling at College quality analysis model.

⑤ Get the optimal parameters and learn the training samples again with the optimal parameters, so as to establish the optimal evaluation model of English classroom schooling quality.

⑥ Test the performance of the established optimal evaluation model of classroom schooling with test sample set, so as to realize the automatic evaluation of English classroom schooling quality.

4. Analysis and Application of English Schooling at College Quality Based on Modern Information Technology

4.1. Application of Data Mining in English Schooling at College Quality Analysis. English schooling at College inherits the benefits of schooling, the most notable of which is high schooling efficiency, which can help to alleviate China's shortage of high-quality talent and meet the needs of national modernization to some extent. As a college public English teacher, we should help students expand their English knowledge, broaden their horizons, and gain a more comprehensive understanding of the quality of English schooling and learning on the basis of a nine-year compulsory education. Data mining has been oriented to the application field to solve practical problems since its inception, and its scope is extremely broad, encompassing almost every industry in the economy and society, including economic management, finance, insurance, electric power, astronomy, and the petrochemical industry. Biology, geography, and geology are three fields of study. Schooling activities, as one of the human cognitive practice activities, have a complex interaction and relationship between teachers, students, and content. Compared with "schooling," teachers are the undertaker and subject of activities, while students are the object and object of teachers' work. Compared with "learning," students are the undertaker and subject of activities, and schooling content is the object and object of activities. However, because many independent colleges and universities take the final English score and English schooling at College-4 pass rate of each semester as the standard to measure teachers' schooling level, most teachers focus on how to improve students' English schooling at College-4 pass rate and examination pass rate, thus ignoring the schooling of English itself. Students cannot understand the charm of English, cannot have interest in English schooling at College quality, and cannot improve their English level. Domestic enterprises applying data mining are led by communication enterprises (China Mobile, China Unicom and China Telecom), and the depth and breadth of application are in a leading position. Domestic banks, insurance companies, and securities companies are also more willing to use data mining technology, which is consistent with the international trend. In the next few years, the application of data analysis in the financial field will definitely develop from traditional statistical analysis to large-scale data mining application.

Due to the large number of students, there are significant differences between students in basic English knowledge and language application ability in the analysis of English schooling at College quality, making it difficult for teachers to accurately grasp the "degree" of schooling requirements in the process of schooling quality analysis. The use of data mining technology by search engine companies is also in high demand. They must employ data mining algorithms to discover the structural and association relationships between web pages in order to better push web pages. In order to maximize commercial profit, major search engines must increase advertising revenue and analyze click stream data.

If schooling is conducted strictly according to schooling requirements, it will put a significant number of students with a weak foundation and lack of ability under psychological stress, causing them to experience excessive anxiety, tension, inferiority, disappointment, weariness, and other emotions. This group of students will eventually stop learning English at a college level. The majority of these students believe that their English learning is inadequate, and even worse, that they are tired of learning, believing that everything will be fine as long as they pass the final exam. Large class schooling of English at College quality still follows the traditional schooling mode, with the schooling goal of mastering language knowledge, the schooling content of words and sentences and discourse analysis, the schooling method of explanation and translation, and a limited ability and energy of teachers due to large class size, unsatisfactory schooling environment, obvious differences in students' levels, and limited ability and energy of teachers. Independent colleges and universities, on the other hand, have no shortage of studious students, and their attitude toward class is correct. Poor English foundation, low learning autonomy after class, quick success in learning English, and a strong purpose are some of their common issues. They want to pass the final exam and complete their English education at College-4, but they refuse to study hard and apply the teaching methods and skills.

4.2. Experimental Results and Analysis. Before the experiment, this paper trains the English schooling at College quality analysis model through 55 training sets. For each training composition, this paper should preprocess it, including segmentation, word segmentation, sentence segmentation, part of speech tagging and dependency parsing. In this paper, 5, 10, 15, ..., 55 English compositions were used for training, and a total of 20 models were trained. The performance of these 20 models was analyzed by using the above experimental evaluation criteria. The experimental results are shown in Figure 4. With the increase of the number of samples, the overall trend of accuracy, recall and F value also increases.

Secondly, through a group of comparative experiments, this paper tests the data mining algorithm and Soon's method on the same test set, and analyzes the advantages and disadvantages of this data mining algorithm. Our test set contains 30 English compositions written by Chinese students, of which there are 1420 entities in total.

The experimental results are shown in Figure 5. On the test set, son's model has accuracy, recall, and F values of

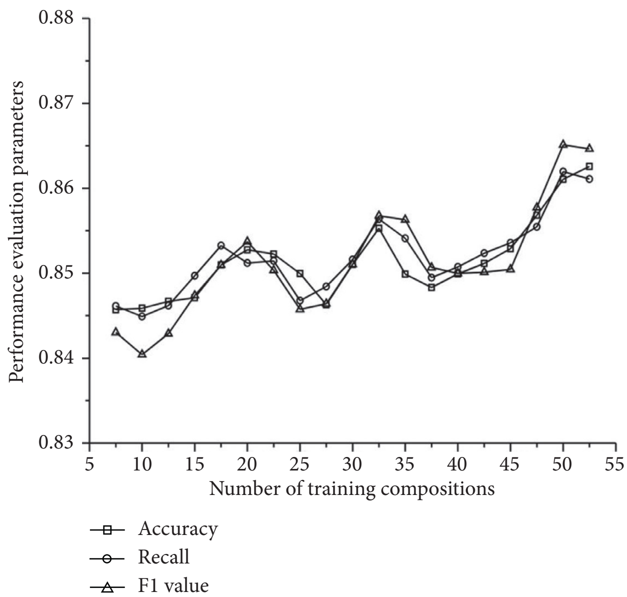

Figure 4: The change trend of accuracy, recall and F value with the increase of sample number.

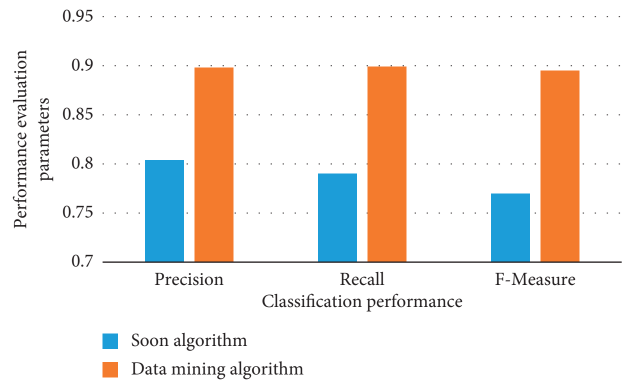

Figure 5: Performance comparison between data mining algorithm and Soon algorithm.

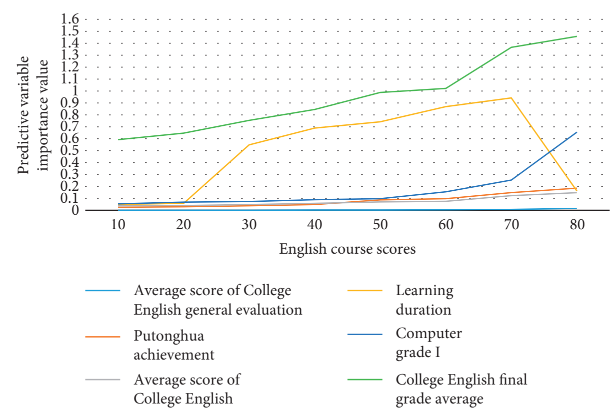

Figure 6: Importance value of each predictive variable.

0.804, 0.79, and 0.77, respectively, whereas the data mining algorithm model in this paper has accuracy, recall, and F values of 0.898, 0.899, and 0.895, which are all better than son's model. This also shows that selecting the right features and adding useful ones can help the data mining algorithm model perform better. Furthermore, the data mining algorithm model in this paper incorporates English schooling at College quality as an external knowledge source, allowing for the discovery of more co referential relationships of English schooling at College quality and an expansion of the co referential resolution range of the soon model.

Because Soon's method is a general method, that is to say, Soon's method may be effective in many fields, the performance of Soon's method on this test set is also better than that on MUC-6 and MUC-7 test sets. However, after feature extraction method optimization and feature design optimization, this data mining algorithm model has evolved into a more targeted co-reference resolution model in the application field, and it has more advantages in the field of English composition than Soon's model.

This study employs a data mining algorithm to construct a prediction model for English schooling at College-4 pass probability of English schooling at College quality analysis of our students by adding modeling attributes and adjusting model parameters in the data mining environment of SPSS modeler, based on students' basic information, English schooling at College quality analysis course scores, and various grade examination scores. By double-clicking on the prediction result node, you can see how important each attribute is. The importance value of each attribute is shown in Figure 6.

The most important factor in passing English schooling at College-4 prediction is "English schooling at College final grade average." The main reason is that the English schooling quality at College is similar to the requirements of English schooling at College-4, and the question types and questions are nearly identical. Both are written examinations that use answer cards to complete questions, according to the examination form. Both the students' knowledge level and examination mentality are taken into account. As a result, if the analysis of English schooling at College quality yields positive results, the likelihood of passing English schooling at College4 will naturally increase, as shown in Figure 7.

The pass rate and average score of English schooling at College 4 are higher for girls than for boys, according to the analysis of the data samples in the figure. The "learning duration" attribute indicates that the length of the learning period has an effect on whether students pass English schooling at College-4. The number of Public English schooling at College semesters for students in grades 2014, 2015, and 2016 is 4 semesters, 3 semesters, and 2 semesters, respectively, according to the school's training programs, and students are not permitted to apply for English schooling at College-4 in the first semester. The data show that during the first semester of an English schooling at College course, the number of English schooling at College-4 students can remain in the three digits, and that the number of English schooling at College-4 students drops sharply after the course, as shown in Figure 8.

It was discovered in a survey of college students' independent learning of English schooling at College quality analysis that "Only 42.5 percent of students can commit to

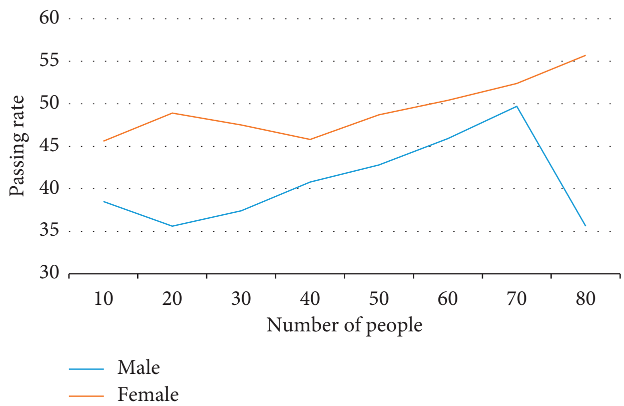

FIGURE 7: Pass rate of English schooling at College-4 for male and female students.

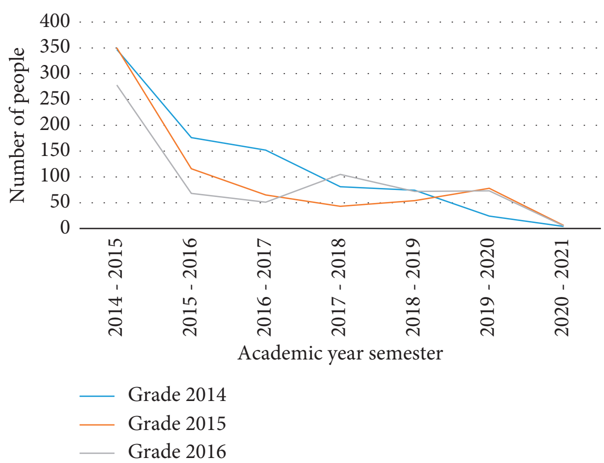

FIGURE 8: Statistics of the number of students passing English schooling at College-4 in each academic year and semester.

4–6 hours of study time per week, and less than 15% can commit to more than 7 hours of study time. Every day, students spend approximately half an hour studying English schooling at College quality analysis." We can see that during the 110 days from March 10th, 2020, to June 28th, 2020 (excluding May Day holiday), online class students spent an average of more than one hour per day on online self-learning, indicating that online English schooling at College quality analysis has played a positive role in stimulating students' learning motivation and enhancing students' self-learning ability, as shown in Figure 9.

At the end of the first semester of the online class, the average scores of each item were 15.5, 30.4, 10.3, 8.6, and 8, respectively, which were 1.2, 1.7, 1.2, 2.1, and 0.6 points higher than those of the non-online class. At the end of the second semester, the average scores of online classes were 16, 32.2, 12.2, 8, 8.6, respectively, which was 2.5, 2.6, 2, 1.6, 0.2 higher than that of non-online classes. The difference of scores shows that students in online classes have steadily improved their English learning scores under the network English schooling at College environment, and the speed of improvement is higher than that of non-online classes, as shown in Figure 10.

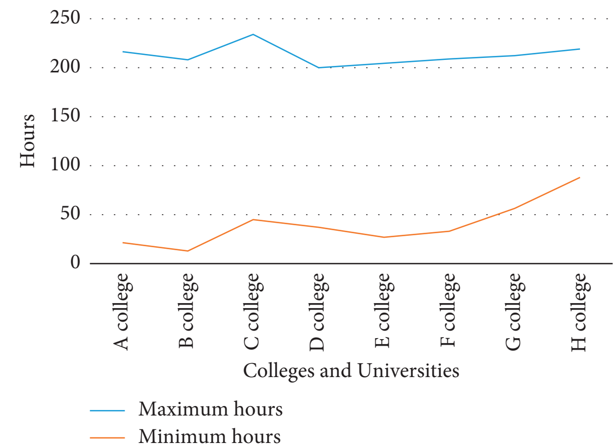

FIGURE 9: Statistics of autonomous learning hours of online English schooling at College for 2020 online class students.

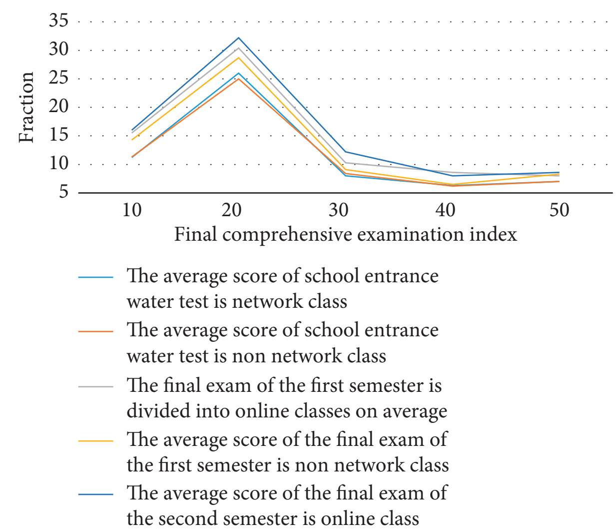

FIGURE 10: Comparison of scores of 2020 online class and non-online class.

5. Conclusions

In today's rapidly changing society and market, data mining technology provides us with methods and means that are unquestionably useful for making decisions. From the perspectives of the evaluation system, teaching mode, and teaching practice, this paper examines the role of network-based college English teaching mode in improving college English teaching quality. We have mastered the use principle of data mining algorithms and the realization of mining through research and practice and have implemented a data mining process using data mining tools. This allows us to gain a better understanding of data mining and lays a solid foundation for future research on the quality of college English teaching and data mining in our work. Educational data mining and analysis methods are becoming more common as educational data mining research advances, and the value of traditional educational data will be rediscovered. As a result, mining large amounts of traditional data is more likely to uncover deep-seated rules of college English development, teachers' teaching, and students' learning, among other things, which will aid in improving college English teaching quality analysis, improving teaching quality, and promoting students' learning.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

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Research Article

Chinese Language Literature Emotion Analysis Model Based on Unbalanced K-Nearest Neighbor Classification Method

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The Chinese language is a nation's symbol, the accumulation of a country's magnificent culture, and the pearl precipitated in the long history's washing. The Chinese language is rich and complex, and there are still many topics and issues that merit repeated exchanges and discussions in academic circles. This study proposes a classification method of emotion polarity based on reliability analysis in order to identify the tendency of literary emotion in Chinese language. Support vector machine (SVM), class center, and KNN (K-nearest neighbor) are included in the combined classifier, which effectively improves the accuracy and efficiency of emotion polarity classification. A Chinese literary emotion analysis model based on the method of UKNNC (unbalanced K-nearest neighbor classification) is proposed at the same time by analysing the characteristics of text structure and emotion expression. The experimental results show that, when compared to traditional machine methods, the UKNNC method can analyse text sentiment in fine-grained and multilevel ways, while also improving the accuracy of Chinese literary sentiment analysis.

1. Introduction

The term "Chinese language and literature" specifically refers to a literary work that is created through Chinese editing and then communicated through Chinese works. The analysis of language application and artistic conception features in Chinese language and literature that follows is useful for improving human language expression ability and application. Using the content covered in Chinese language and literature can help students improve their language skills, improve communication with others, expand their thinking abilities, and better taste Chinese language and literature works. In essence, students can only grasp the applied context effectively if they have a broad understanding of Chinese language and literature, which helps to improve students' overall Chinese literacy.

Emotion analysis of Chinese language and literature refers to judging its emotion tendency by analysing and mining information such as emotions, positions, and opinions in the text [1]. It involves many fields such as data mining, information retrieval, and so on, and has a wide range of application value. Data level processing is very important for unbalanced classification [2, 3]. No matter whether the importance of samples is consistent in practical problems, data level processing will have a relatively positive impact on the final classification results. Traditional learning analysis techniques in the field of education frequently focus on analysing structured data but rarely consider unstructured data, making it difficult to accurately identify learners' attitudes, emotions, and psychological states [4, 5]. The support of classification methods is essential for successful classification of imbalanced data sets, and a good classification method is the key to success. When traditional classification methods are used to classify imbalanced data sets, however, test samples from a few classes are frequently misclassified into the majority of classes, making it easy to overlook a few classes and resulting in poor classification performance [6]. Because the complex distribution of unbalanced data is difficult to capture, current technology in this field still has many flaws. As a result, investigating an effective unbalanced data classification technology [7] is extremely important.

K-nearest neighbor (KNN) method has become one of the most famous algorithms in the field of pattern recognition [8–10] and statistics because of its simple algorithm, easy realization, no need to estimate parameters, and high classification accuracy, and it is also one of the earliest nonparametric algorithms applied to automatic text classification in machine learning [11, 12]. However, KNN method needs to store all the training sample data in the process of calculating the nearest neighbor of each sample to be tested, which leads to a large number of similarity calculations for classification and significantly increases the complexity of classification calculation with the increase of sample data set [13], thus reducing the classification efficiency. Based on this, this study puts forward a Chinese literary sentiment analysis model based on the method of unbalanced K-nearest neighbor classification (UKNNC) for learners' learning experience texts, which classifies the learning experience text information in multiple levels to improve the performance of learners' sentiment analysis and provide more effective support for teaching design and management.

Emotion analysis of Chinese literature belongs to the category of computational linguistics, which involves many research contents such as artificial intelligence, machine learning, information extraction, information retrieval, and data mining. It is closer to the goal of artificial intelligence than traditional technology, and has important research value in theory and application. Therefore, this study innovatively proposes an emotion analysis model of Chinese language literature based on UKNNC method. The difference between this method and the traditional voting strategy of combined classifiers lies in whether to vote on the categories of samples by multiclass classification by analysing the credibility of samples. Experiments show that the classification speed of this method is lower than that of SVM.

2. Related Work

As far as the nature of Chinese language is concerned, it involves a wide range of majors, but as a whole, liberal arts students are the main teaching objects, and some students do not study Chinese language and literature until they enter the university, which also reflects the charm of Chinese language and literature from the side, and makes the analysis of language application and artistic conception get corresponding attention and attention. Literature [14] puts forward Fisher discrimination rate that calculates the distance between positive and negative classes of each feature. The larger the distance, the easier it is to classify the data. Literature [15] puts forward the complexity measurement (CM) as the data set measurement index, and CM calculated the proportion of less than half of the samples in the nearest neighbors of the samples in the data set. The larger the CM, the larger is the cross between positive and negative samples. When IR is used as the data set evaluation index, there is no fixed value range of IR, but the CM range is 0–1, which makes it more comparable. Literature [16] holds that each sample has its neighbor distribution. When the sample is surrounded by samples of the same kind, the classification of the sample is simple, while when the sample is surrounded by samples of different kinds, the classification of the sample will be more difficult. In literature [17], the author used Naive Bayes and maximum entropy method to study the emotion classification of news and commentary corpus. Through experiments, it was found that the accuracy of binary value as feature weight was better. Literature [18] has studied the correlation between the extracted subject and the evaluation words of rhetoric. They introduce the relationship extraction into data mining, take the evaluation words and subjects co-occurring in the same sentence as candidate sets, and apply the maximum entropy model to extract the relationship with various features, such as words, parts of speech, semantics, and positions. The results show that degree adverbs can help improve the performance of subjective relation extraction.

In terms of classification method selection and design, it is primarily based on a thorough examination of the degree of influence of indexes (parameters, structures, and so on) of traditional methods on unbalanced data sets, with corresponding improvements to existing methods or the creation of new classification methods. The original training samples are primarily clustered or blocked in literature [19], and then representative training samples are selected to replace the original training samples. The literature [20] divides samples based on density. The KNN rule of distance weighting is based on the characteristics that the nearest neighbor points near the test sample contribute a lot to classification, whereas the opposite contribution is small, according to literature [21]. Literature [22, 23] proposes a generalised nearest neighbor classification method that assigns different weights to each dimension of classified data. The importance of boundary samples has been improved in the literature [24]. Literature [25] defines the representative function from two factors: the distance between two samples and the included angle and replacing the category attribute function with the defined function when calculating the weight by KNN method. In literature [26, 27], by summarizing the construction of praise and derogatory words, the table of influencing factors, the matching word list, and the clear word list in the field of electronic products, an evaluation system for electronic products was constructed, and the opinion mining of electronic products was realized, with the correct rate reaching 93%.

Emotion classification and extraction, as the basic research of emotion analysis, provide effective support for the application of emotion analysis, but there is still a big gap between the results of classification and extraction and the specific needs of users. Therefore, in order to narrow the gap with users' needs, the application research of emotion information becomes essential.

3. Research Method

This study examines the problem of Chinese literary emotion analysis, adopts the classification method of emotion polarity based on reliability analysis and the model of Chinese literary emotion analysis based on UKNNC method, and makes an in-depth study with various linguistic features, which greatly improves the effect of Chinese literary emotion analysis as a whole.

3.1. Traditional KNN. On the basis of the nearest neighbor method, the K-nearest neighbors (KNN) method was developed. It is one of the most widely used classification methods in the fields of data mining and machine learning, as well as the US Census Bureau's default data preprocessing method. It is now widely used in a variety of fields, including classification, clustering, and regression. This study will focus on how it can improve its classification.

Emotion tendency includes two categories: positive and negative. Therefore, emotion recognition can be regarded as two kinds of classification problems, namely, the recognition of positive and negative meanings. Based on this, KNN algorithm is used to identify the emotion of the text. The algorithm is a simple, effective, and nonparametric method, its essence is a predictive supervision algorithm, and its rules are data samples [28].

KNN's classification idea is very simple, that is, suppose that for a given sample $D = D(d_1, d_2, \ldots, d_l)$ to be classified (where l is the dimension of the sample), the computer trains the training data sets of known categories, finds out the k nearest neighbor samples most similar to D from these training data sets, and then classifies and votes D to determine its category.

Suppose the training set is

$$T = \{X, C\} = \{x_i, c_i\}_{i=1}^{n}, \quad x_i \in R^l. \tag{1}$$

Here, X is the training sample set, C is the category of training sample set, and test set is $S = \left\{x_j\right\}_{j=1}^{m}$.

The traditional KNN method mainly finds out the k training samples with the highest similarity with x_j from the training sample set X of known categories for each sample x_j to be tested:

$$M = \{X', C'\} = \{x_d, c_d\}_{d=1}^{k}, \quad M \in T. \tag{2}$$

The similarity of each sample x_i and x_j in the training sample set X is calculated as follows:

$$Sim = \left(x_i, x_j\right) = \frac{\sum_{t=1}^{n} w_{it} w_{jt}}{\sqrt{\sum_{t=1}^{n} w_{it}^2} \sqrt{\sum_{t=1}^{n} w_{jt}^2}}. \tag{3}$$

Here, w_{it}, w_{jt} represent the weight of the t-th feature item in samples x_i and x_j respectively, and the weight calculation formula of x_j belonging to class c_t is as follows:

$$W\left(x_j, c_t\right) = \sum_{x_i \in x_j} v\left(x_i, x_j\right) \phi\left(x_i, c_t\right). \tag{4}$$

Among them, $v(x_i, x_j)$ is the weight function of voting, generally taking 1 or $Sim = (x_i, x_j)$, and the ϕ function is as follows:

$$\phi\left(x_i, c_t\right) = \begin{cases} 1, & x_i \in c_t, \\ 0, & x_i \notin c_t. \end{cases} \tag{5}$$

x_j is classified into the category with the largest class weight W. Repeat this process to classify all samples to be tested. Finally, the classified category is classified with its real class label to measure the performance of this classification method.

The original KNN algorithm's classification principle is simple and straightforward to use, but there is no systematic consideration of the impact of sample data set imbalance on classification, that is, each selected nearest neighbor sample's representative degree to its class is treated the same. To solve this problem, an improved KNN algorithm is proposed in this study. This method primarily improves the algorithm in two areas: sample set imbalance between classes and sample set imbalance within classes.

3.2. Text Emotion Information Classification. The classification of text emotion information is primarily used to identify opinions, attitudes, preferences, and other related information expressed in natural language. Emotion classification research focuses on unstructured text information such as forums and blogs that come in a variety of formats and are written in a colloquial style. Emotion classification, unlike traditional topic-based text classification, focuses on subjective and objective classification, as well as emotion polarity classification. It is mainly divided into word-level emotion information classification, text-level emotion information classification, and sentence-level emotion information classification, depending on the granularity of the research.

Level-I sentiment information classification includes subjective and objective text classification and text sentiment polarity classification. The process is shown in Figure 1.

The mainstream method used in the classification of level-level emotion polarity is the classification method based on statistical learning. From the existing related research, it is found that the classification method based on statistics is also the most effective method to solve the classification of emotion polarity at present. In the existing research, scholars have tried to apply various statistical classification methods and linguistic features such as words and parts of speech to the study of emotion polarity classification, and achieved good results [29]. In order to further improve the classification accuracy, this study looks at two aspects: optimising the classification model and selecting effective features.

This study proposes a combined classifier method based on reliability analysis for optimising classification models. This study employs a method based on category attribute analysis for feature selection. Experiments show that the method used in this study can effectively improve classification accuracy without slowing down the classification process.

In the process of emotion polarity classification, through the analysis of emotion information, it is found that not all samples need to be discriminated by combined classifiers, and there is no obvious difference in the classification results of various single classifiers for samples that are easy to distinguish.

From Figure 2, we can see that the hollow circle and square respectively represent different types of sample points, and the circle and square which are far from the

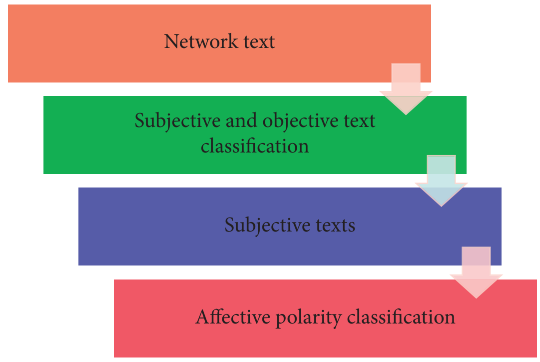

Figure 1: Emotion information classification process.

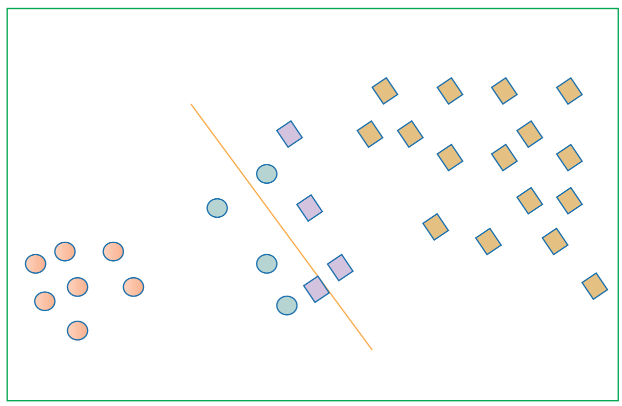

Figure 2: Schematic diagram of binary classification sample distribution.

classification hyperplane respectively represent samples with obvious classification characteristics.

Therefore, if we can find a way to determine which samples belong to easily distinguishable samples and which samples belong to indistinguishable samples, then we can treat the two types of samples with different methods and improve the accuracy and speed of classification. In this section, a classifier fusion strategy based on reliability analysis is proposed to solve the polarity classification problem of these samples.

Assuming that a confidence function $f(x)$ is determined according to the classification principle of the main classifier, and the discrimination threshold $\lambda\,(\lambda > 0)$ is set, if $f(x) > \lambda$ is used when the main classifier discriminates the samples, it is considered that the discrimination result of the main classifier has high confidence, and the result can be used as the final classification result of the samples.

Otherwise, the classification of the sample to be marked is determined by the method of voting together by the main and auxiliary classifiers. The discrimination process is shown in Figure 3.

We define the credibility function according to the distance between the test sample in the main classifier and the class center, as shown in the following formula:

$$f(x) = \frac{f_1}{f_2}, \tag{6}$$

where f_1 is the distance between the nearest class center and the test sample, and f_2 is the distance between the next nearest class center and the test sample.

It can be analysed that when the cosine similarity is used to calculate the distance between the sample and the class center, if $f_1 > f_2$, it means that the distance between the test sample and the nearest class center is relatively close, and the distance from the next nearest class center is relatively far, and this kind of sample is considered to be relatively easy to distinguish.

If $f_1 < f_2$, it means that the distance between the test sample and the nearest class center and the distance between the next nearest class center may be relatively close, and this kind of sample is considered not easy to distinguish.

In the classification problem, apart from the classifier used, the influence of feature selection on the classification results is also very important. The feature selection algorithm adopted in this chapter is a feature selection algorithm based on category attribute analysis [30], which has achieved good results in traditional text classification. The formal description of feature selection algorithm based on category attribute analysis is as follows:

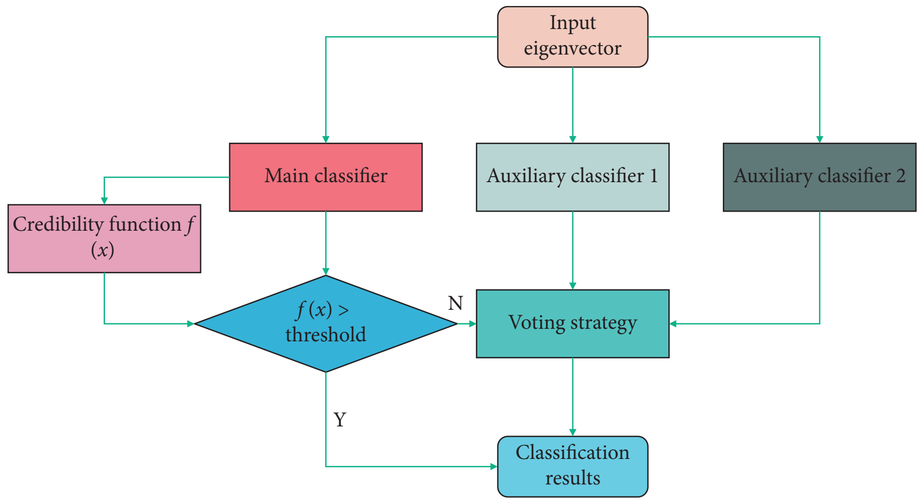

Figure 3: Discriminating process of combined classifier.

Let us assume that $X = (\omega_1, \omega_2, \ldots, \omega_n)$ represents a text, and $C_j = (X_1^j, X_2^j, \ldots, X_{n_i}^j)$ represents a text set with n_i texts and the category mark C_j, $j = 1, 2, \ldots, m$. The following formula represents the intraclass distribution law and interclass distribution law of feature ω_i in text class C_j.

Assuming that the word frequency of feature ω_i in C_j is T_{ij} and the document frequency is d_{ij}, the distribution within the class is as follows:

$$S\omega_{ij} = \frac{f\omega_{ij} \cdot \log\left(d\omega_{ij} + 1\right)}{\sqrt{\sum_{i=1}^{n} \left[f\omega_{ij} \cdot \log\left(d\omega_{ij} + 1\right)\right]^2}}. \tag{7}$$

Here, $f\omega_{ij} = T_{ij}/L_i$, L_i is the number of times ω_i appears in all categories; and $d\omega_{ij} = d_{ij}/D_i$, D_i is the number of all texts where ω_i appears.

Class distribution is recorded as follows:

$$B\omega_i = \left(S\omega_{i1}, S\omega_{i2}, \ldots, S\omega_{im}\right). \tag{8}$$

Generally, when the components of the distribution vector between classes differ greatly, the feature has a strong ability to distinguish between classes. When the components of the interclass distribution are similar or identical, the feature's ability to distinguish between classes will be very low, so the feature's resolution can be expressed as follows:

$$\mathrm{Im}p\left(\omega_i\right) = \sqrt{\frac{\sqrt{\sum_j \left(S\omega_{ij} - \bar{S}\omega_i\right)^2}}{\sum_j S\omega_{ij}}}. \tag{9}$$

In the above formula, $\bar{S}\omega_i = \sum_j S\omega_{ij}/m$.

From the above formula, we can find that the feature selection method based on category attribute analysis pays attention to the distribution of features within and between classes and quantitatively describes this distribution through variance mechanism. The features retained by the algorithm usually have obvious category attributes, so these features have strong representation ability to the corresponding categories, whereas those filtered out features have weak or zero representation ability.

3.3. An Analysis of Chinese Literary Emotion Based on UKNNC

The classification algorithm and the traditional oversampling algorithm are separate. To train the classifier, new samples are first generated and then added to the training set. The test results reflect the quality of samples after the classifier has been trained. However, the advantages of the oversampling algorithm in generating samples are not fully exploited in this framework, and the role of the samples generated in oversampling on the classifier cannot be guaranteed.

This study starts with the goal directly, draws on the idea of confrontation architecture, and proposes the concept of expected classifier, which refers to a new classifier trained by the current classifier under the update of synthesised samples, in order to accurately measure the quality of synthesised samples and judge whether samples can truly improve the performance of classifiers.

Assuming that the classifier used is a single-layer neural network, the influence of the new sample on the performance of the classifier is influenced by the update on the w, b of the classifier, that is, if the w, b calculated by the new sample are in the same direction as the calculation gradient of the original sample, they will reduce the loss function value of the original sample on the new network parameters, and the update of the parameters on the new sample is shown in the following formula:

$$\begin{aligned} w &= w - \eta \frac{\partial \mathrm{loss}}{\partial w}\left(x = x_{\mathrm{new}}\right), \\ b &= b - \eta \frac{\partial \mathrm{loss}}{\partial b}\left(x = x_{\mathrm{new}}\right). \end{aligned} \tag{10}$$

Let the classification cost function use cross entropy, which is defined in the following formula:

$$\begin{aligned}
\operatorname{loss}(y, \hat{y}) &= -\sum y \log \hat{y} + (1-y)\log(1-\hat{y}),\\
d\hat{y} &= -\frac{y}{\hat{y}} + \frac{1-y}{1-\hat{y}},\\
z &= w^T x + b,\\
\hat{y} &= s(z),\\
dz &= \hat{y}(1-\hat{y}) \times d\hat{y} = \hat{y} - y,\\
db &= dz = \hat{y} - y,\\
dw &= x dz = (\hat{y} - y)x.
\end{aligned} \tag{11}$$

The specific steps of the improved KNN classification are as follows:

Input: training sample set $T = \{X, C\} = \{(x_1, c_1), (x_2, c_2), \ldots, (x_l, c_l)\}$.

Among them, $c_i \in D\{c_1, c_2, \ldots, c_{|C|}\}$ is sample category, and $i = 1, 2, \ldots, l$, sample to be tested x_j.

Output: the class C to which the sample x_j to be tested belongs

(1) Standardization:

$$X_{\text{new}} = \frac{X - \min(X)}{\max(X) - \min(X)}. \tag{12}$$

(2) Calculate the class representation and sample representation of each class.

(3) Calculate the similarity of each sample x_i and x_j in the training sample set X.

(4) Calculate the weight $W(x_j, c_t)$ of the class to which the selected k samples belong, and assign x_j to the class with the largest weight.

(5) Repeat the above steps until all samples to be tested are classified.

UKNNC algorithm uses variational self-encoder as the $P(X)$ model for modeling in oversampling. When training the classifier, because incremental classifier is used, the modification direction of new sample to classifier can be calculated. When the expected classification result of classifier is poor, it means that the modification direction of new sample to classifier is wrong, so the parameters of generator are modified. The flow of UKNNC algorithm is shown in Figure 4.

4. Analysis and Discussion

4.1. Improved KNN Experimental Analysis. In the experiment, the traditional KNN method and the improved KNN method are used to experiment when the nearest neighbor parameter k takes different values, and the results are shown in Figure 5.

When the traditional KNN method is used to classify the experimental data set, the accuracy is the highest when the parameter $k = 50$, while when the improved KNN method is used, the parameter $k = 20$ is the best, so $k = 20$ is finally selected uniformly after comprehensive consideration.

When $k = 20$, the accuracy, recall, and comprehensive classification rate obtained by using the improved classification method on the above data set are shown in Figure 6.

It can be seen from Figure 6 that the improved KNN method proposed in this study has higher accuracy than the existing KNN method on data sets 3, 4, 5, 6, 7, and 8. Especially, on data sets 3, 4, and 8, the original 0 has been improved to a certain accuracy, but only on data set 9, the accuracy has not changed, which is mainly due to the fact that there are few such data sets and the degree of similarity with category 8 is too great.

To summarise, the improved KNN method proposed in this study adopts the idea of weighted calculation of nearest neighbor samples, aiming to solve the problem of equal weight treatment of nearest neighbor samples in the existing KNN method. As a result, each nearest neighbor sample has a specific weight, reducing the impact of unbalanced data sets on classification results and improving classification accuracy.

4.2. Analysis of Polarity Classification Results. In the experiment of Chinese language and literature emotion corpus, documents are represented by vector space model, feature selection algorithm based on category attribute analysis is used, term frequency-inverse document frequency (TF-IDF) value is used as feature item weight, and Chinese word segmentation system uses ICTCLAS3.0 of Chinese Academy of Sciences. The value of k in KNN method is 100.

Figure 7 shows the classification comparison results of the reliability analysis method at $\lambda = 2$, three single classifiers and voting method under the 50% cross-validation method. Among them, for the credibility analysis method, 44.83% of the texts need auxiliary classifiers to participate in voting decisions.

It can be seen from Figure 7 that among the three single classifiers, support vector machine (SVM) has the best classification effect, followed by the classification results of class center and KNN. The F value of reliability analysis is 1.7% higher than that of SVM, which is basically the same as that of voting method.

Chi-square significance test shows that the performance improvement of the method proposed in this study is statistically significant ($p < 0.05$) compared with other methods, which shows that the classification accuracy of the classification fusion strategy based on reliability analysis can exceed the results of SVM model under the condition of setting a reasonable threshold.

In addition, in order to verify the classification speed of reliability analysis method, the classification speed was tested on a computer with CPU frequency of 2.6 GHz and memory capacity of 3.8 GB. The average test result is shown in Figure 8.

Referring to the classification speed values of each single classifier obtained in Figure 8, we can see that the classification speed of the class center method is the fastest, and that

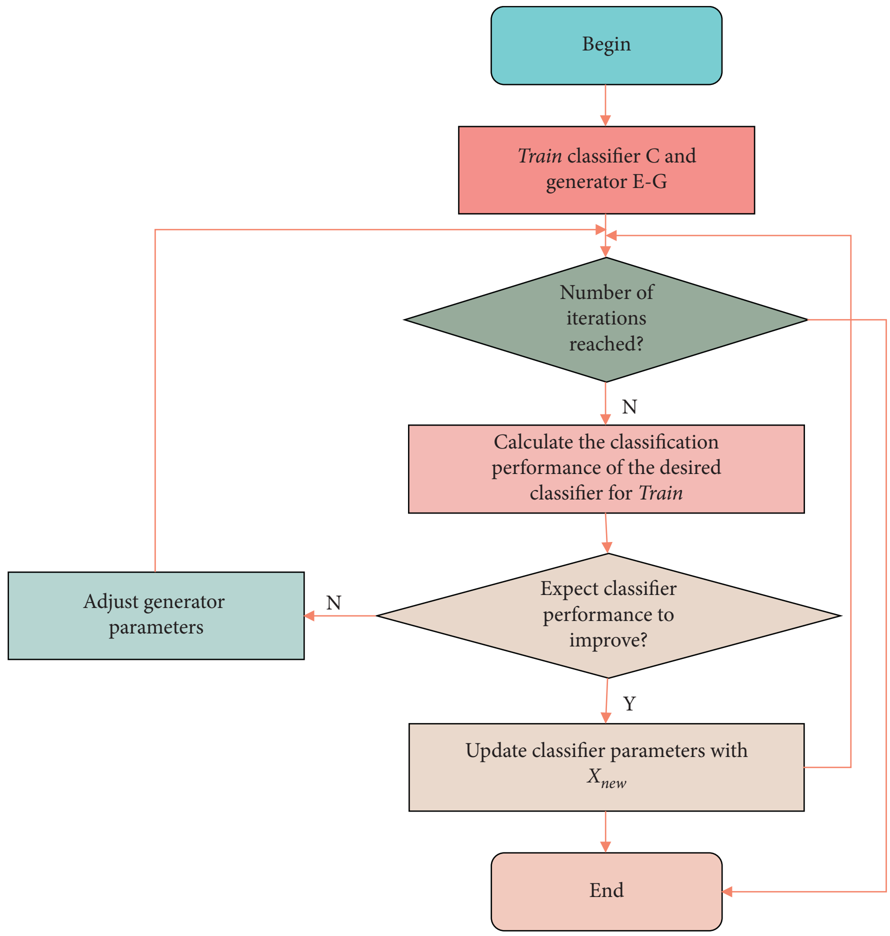

Figure 4: UKNNC algorithm flow chart.

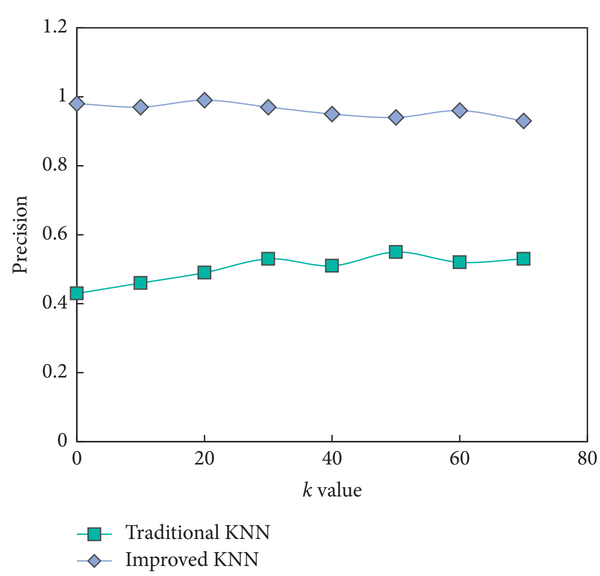

Figure 5: Experimental results of KNN precision before and after improvement.

of the SVM method is the slowest, while the speed of the credibility analysis method is obviously higher than that of SVM, which is between the class center and SVM.

Compared with the voting method, the speed of the credibility analysis method is obviously improved, which shows that the combined classification method based on credibility analysis has an obvious improvement effect compared with SVM and voting method in classification speed under the condition of setting a reasonable threshold.

In the evaluation, two groups of evaluation results of credibility analysis method and single classifier SVM are presented, respectively. The specific evaluation results are shown in Figure 9:

From the evaluation results, it can be seen that the results of reliability analysis method are lower than those of SVM on R-Accuracy and Acc_1000. The reason is that the evaluation does not provide training set, but the test set covers a wide range of fields, which leads to a great difference in the feature distribution between the test set and the training set.

The λ value obtained through the development set cannot well reflect the sample distribution characteristics of the test set, which may lead to the results of reliability analysis method being lower than SVM on some indicators.

To sum up, when the reasonable threshold λ is determined, the credibility analysis method can get better results than SVM method in classification speed and accuracy. At the same time, because the combination classification method based on credibility analysis can ensure faster

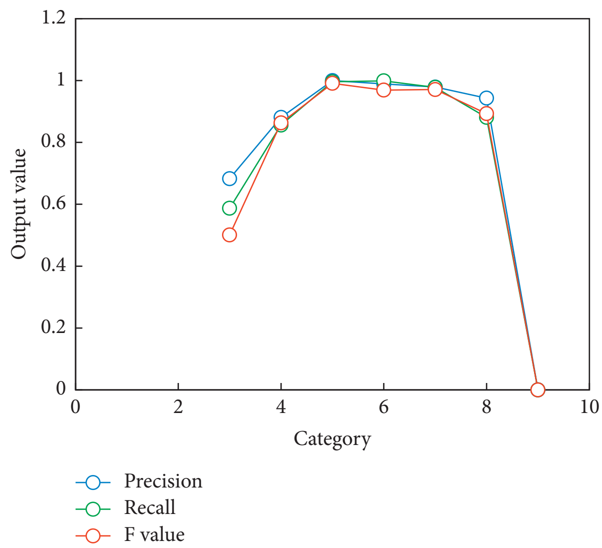

Figure 6: Experimental result comparison data set.

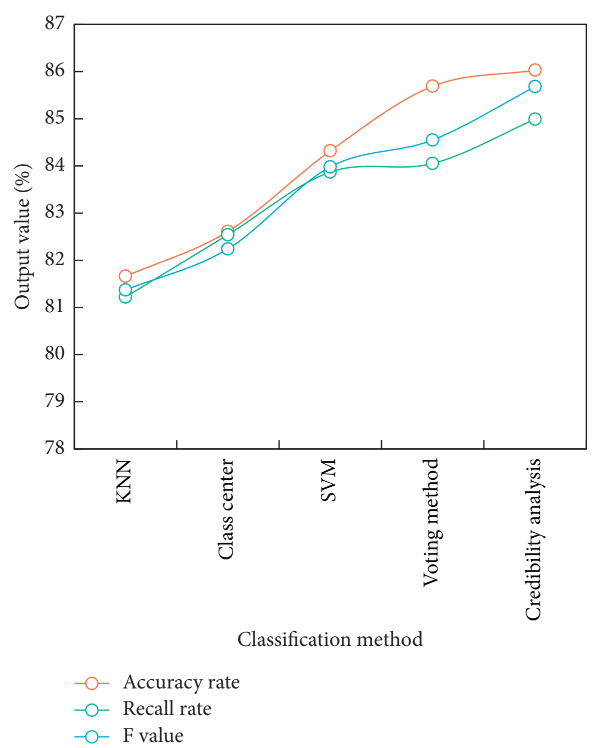

Figure 7: Emotion polarity classification result.

classification speed and better classification accuracy, it is more suitable for emotion classification of large-scale online texts.

4.3. Validity Verification of Unbalanced Classification Algorithm. In this section, in order to verify the rationality of the UKNNC algorithm, the classifier uses a single-layer neural network. The network architecture is consistent with that of the UKNNC algorithm, and it is consistent with the UKNNC algorithm in terms of training times and learning rate.

The VAEOS algorithm is used to generate a few samples that are added to the training set to directly train the LR classifier in order to compare the joint oversampling algorithm with the independent oversampling algorithm. To avoid randomness, the average of 10% cross validation is used in this section as a comparison between the joint oversampling algorithm and the independent oversampling algorithm.

Because it is necessary to make assumptions about the form of data distribution in an oversampling algorithm based on data distribution, this type of algorithm has higher requirements for the form of data distribution, as shown in Figure 10.

Ideally, the oversampling algorithm based on data distribution first reconstructs the probability distribution function of data and then conducts more intensive sampling according to the distribution function. The credibility of sampling results depends on the credibility of modeling. The improvement of classifier performance by the oversampling algorithm based on data distribution depends on whether the current sample meets the hypothesis. Therefore, in UKNNC, when there is no need to set the hypothesis of the true distribution form of samples, the modeling reliability of the algorithm for minority classes will increase, so the generated samples have higher reliability, which shows that the classification performance of minority classes is better.

Figure 11 shows the comparison of the classification performance of CGMOS in the case of Naive Bayes classifier and logistic regression classifier. From the experimental results, it can be seen that due to the different data characteristics, the experimental results are better than other frameworks on the data set that fits the classifier.

However, it synthesizes samples for Bayesian framework classifier, so the classification results on multiple data sets are similar to those of VAEOS algorithm on naive Bayes. All the results of UKNNC algorithm are better than those of VAEOS algorithm under LR classifier, which proves the effectiveness of UKNNC algorithm and joint oversampling algorithm.

Because the data sets in this study are all numerical values, the average classification value of Naive Bayes is slightly lower than LR. In order to obtain a better classification effect, firstly, the classifier should be selected according to the data characteristics; secondly, the oversampling algorithm has a higher probability to improve the classification effect. However, the joint oversampling algorithm based on the characteristics of the classifier has better promotion effect on the classification algorithm in its own framework.

After comparison, all the classification indexes are superior to the emotion classification results of other emotion dictionaries, which not only shows the effectiveness of introducing the expression dictionary to the analysis of Chinese literary emotion but also verifies the application value of the UKNNC method proposed in this study.

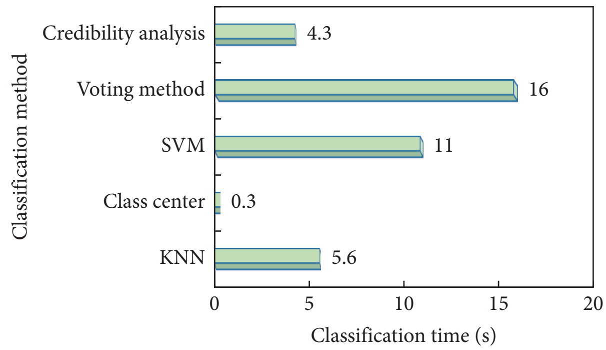

Figure 8: Classification comparison result.

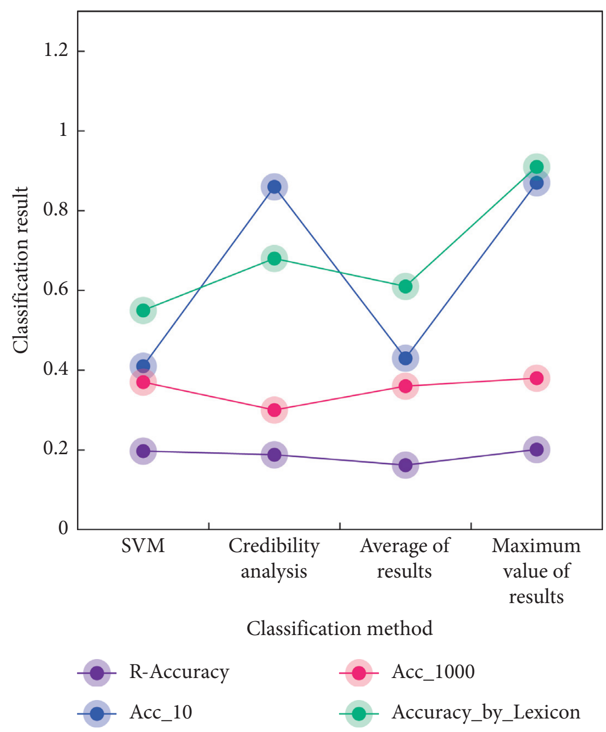

Figure 9: Emotion classification evaluation results.

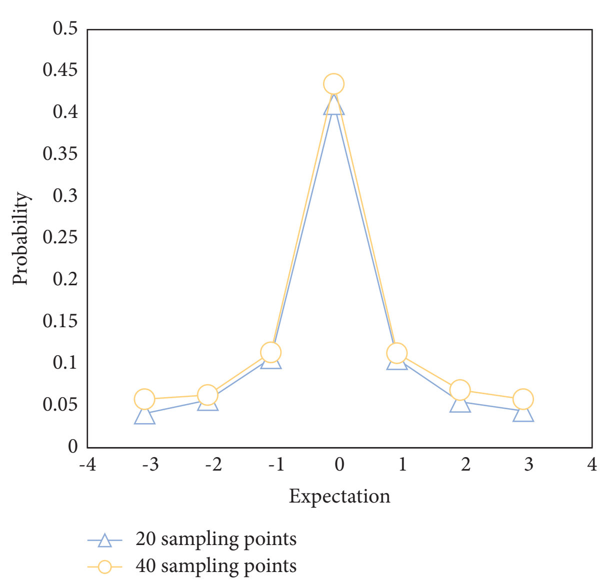

Figure 10: Different sampling points.

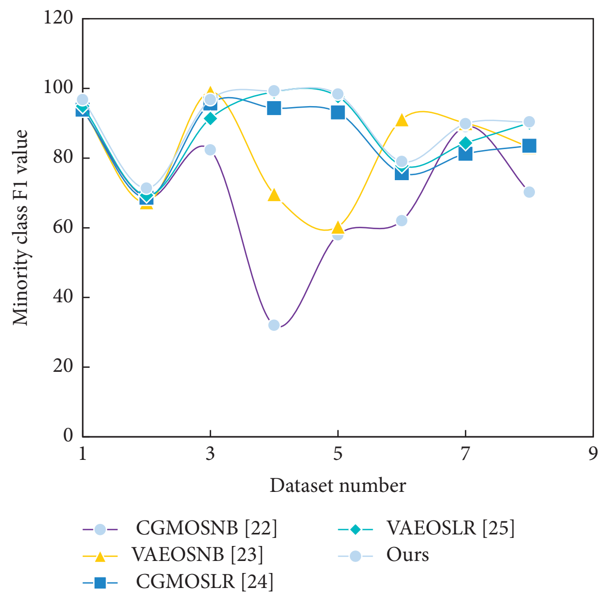

Figure 11: Comparison of oversampling algorithms in different classification frameworks.

5. Conclusion

Chinese development has been shaped by thousands of years of precipitation, resulting in unique aesthetic characteristics that are extremely appealing. We should pay attention to the beauty of temperament when writing poetry. Music is frequently used in the creation of ancient poems. The beauty of images should be considered when describing lyricism. Different images are used to convey specific emotions, and the same images can convey joy and sorrow on multiple levels. The use of reliability analysis to classify emotion polarity is proposed. Experiments show that this voting method based on credibility analysis can outperform SVM in terms of classification accuracy, though its classification speed is slower than SVM's when the appropriate credibility threshold is selected. Simultaneously, a UKNNC-based emotion analysis model of Chinese language literature is proposed, with the emotions of each paragraph in the text obtained through the two-layer model. The experimental results show that, when compared to the traditional machine learning analysis method, the emotion analysis method proposed in this study significantly improves the accuracy of Chinese literary emotion recognition.

Currently, the expected classifier is calculated using synthetic samples and random gradient descent. There is still a lot of analysis and design work to be done on how to use a more accurate gradient descent method and how to avoid prematurely falling into a local optimum in order to stop training.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Intelligent Resource Allocation for Ultradense Networks Based on Improved Reinforcement Learning

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The urgent need of high-quality mobile services and improved user experience has driven to develop high-capacity mobile network system. To achieve this goal, ultradense network (UDN) has been widely considered as one of the promising solutions that significantly expand the network capacity. However, as the communication resources and the number of links per unit area are extremely densified within UDN, efficient and high-quality scheduling and resource allocation for UDN become challenging. Even worse, the complex environment of UDN limits the direct adoption of traditional allocation schemes to UDN. In this manuscript, the author is going to propose an efficient resource allocation algorithm for UDN based on deep reinforcement learning. First, the author presents the resource allocation strategies in cellular network server based on double Q-learning. Then, the author optimizes the algorithm by pruning redundant model weights and making a tradeoff between computational complexity and performance to meet the requirements of low latency and limited computing costs. The experiment and simulation results show that the pruning algorithm effectively reduces 50% model parameters. The UDN allocation performance is still acceptable as the proposed algorithms save up to 50% complexity.

1. Introduction

The rapid growing need of high-quality mobile services and improved user experience has become a driving force for a high-performance mobile network. On the other hand, the improved efficiency and higher network performance enable emerging user experiences as well as novel applications, like the next-generation smart Industry 4.0 [1]. The need for connection speed and data traffic is both growing at an exponential rate. According to some reports [1, 2], the data rates are projected to increase by around ten times every five years. Moreover, trillions of mobile devices and sensors will be connected together across the world via wireless network. The upcoming Internet of Things (IoT) and future fifth-generation (5G) mobile networks will encounter a halt unless we can rapidly increase the capacity of current communication system. Therefore, a paradigm shift and enhancement in every aspect of current mobile network system are required to provide the immense amount of data traffic arising from high-resolution video applications [2]. In the next-generation communication system, many ideas and schemes are proposed to resolve the challenges imposed by the requirements of a lower network latency, higher peak data rates, more reliable connection stability, increased availability, and better user experiences.

The opportunities of 5G system have attracted great attention from academics, industries, and governments. Among the above-mentioned points, how to develop a high-performance network that offers massive capacity within a dense area becomes one of the major challenges. Ultradense network (UDN) is one of the promising solutions where the communication nodes and the number of links per unit area are extremely densified. Rather than focusing on the evolutionary improvements of previous generations in terms of spectral efficiency, the densification of network is able to bring about more significant overall system performance gain by dramatically increasing the network infrastructures [3]. The definition of UDN varies among different literature. Basically, UDN can be abstracted as a special type of network with very dense radio resources than current networks.

Specifically, UDN is equipped with tremendous amounts of base stations (BSs) with higher density, where the BS density reaches and even exceeds the user density. Besides, an UDN can also be modeled a network where the intersite wireless access points (APs) are separated by only a few meters.

However, UDN also faces several significant hurdles towards the way to constructing high-capability and high-efficiency mobile network. The factors causing the challenges include the dense radio resources, mobility, and interference between devices. Although the dense cellular networks can efficiently offload data traffic from traditional macro cellular networks, how to optimally allocate and schedule the available network resources affects the overall network performance and user experience. This makes the resource allocation algorithms of UDN a crucial part when design UDNs. Tremendous amounts of previous research works have studied the resource allocation policies in various perspectives, including UDN as well as heterogeneous network scenarios (HetNet) scenarios. The authors in [4] propose a novel UDN resource allocation algorithm that has low computational overhead. However, the resulting quality of resource allocation under fast changing and complex network environment is not satisfactory. To improve this shortcoming, deep reinforcement learning-based scheduling algorithms are presented in [5, 6]. But the limitations of these two algorithms lie in that they are still computationally intensive workloads, which are not suitable to be employed in UDNs with different sizes.

In this paper, we propose deep reinforcement learning-based resource allocation scheme to address the abovementioned challenges. Our algorithms can be efficiently applied to allocate UDN resources in the 5G scenario. The following parts summarize our contributions:

(i) We first model the mathematical model of resource allocation for UDN. Then the NP-hard nonconvex resource allocation problem in UDN is transformed into a form that can be solved by deep reinforcement algorithm.

(ii) A novel and efficient resource allocation algorithm based on deep reinforcement learning is proposed to achieve near-optimal resource allocation under different communication environments.

(iii) We also consider the efficient implementation problem of deep reinforcement learning-based resource allocation algorithm. The weight and model pruning schemes are utilized to train low-complexity models.

(iv) Compared to previous works, our work further considers the factors of computing power-constrained scenarios. The optimized (pruned) algorithms are able to perform energy-efficient resource allocation.

The rest of this paper is organized as follows. Section 2 introduces the system model and problem formulation for UDN resource allocation. Section 3 presents the proposed algorithms and optimization methods. Section 4 presents the simulation and experiment results. Section 5 concludes the whole paper.

2. System Model and Problem Formulation

To accurately model the resource allocation problem, we choose to use the ultradense networks of 5G downlink, as shown in Figure 1. In the following parts, we summarize the main points of this model according to [7]. In this case, a total of N small base stations (SBSs) will be randomly distributed within the area of one macro cell. In the center of the macro cell, one macro base station (MBS) is placed to process the incoming data and perform scheduling policies. Inside the MBS, a mobile edge computing (MEC) server is installed that is responsible for computing and allocating resources for the whole UDN.

Without loss of generality, we define the set of N SBSs as the form: $\mathcal{N} = [1, 2, \ldots, N]$. Many small user equipments (SUEs) will randomly present and move within each SBS. The arrival of users is considered as a random process. Moreover, the user arrival and departure are regarded independent. Hence, the arrival of each SUE to each micro cell is parameterized with a Poisson process and parameter λ_t. For each time slot, the probability that a total of n new SUEs will arrive in the micro cell, and this can be expressed as the following equation:

$$P(n) = \frac{(\lambda_t \tau)^n}{n!} e^{-\lambda_t \tau}, \tag{1}$$

where τ denotes the time period. The probability of SUEs that will leave the small cell can also be modeled as a Poisson process similar to equation (1) with a different parameter μ_t.

We denote the SUE set as $\mathcal{U}_n = [1, 2, \ldots, U_n] (n \in \mathcal{N})$. Outside the micro cell, there would be some macro user equipments (MUEs) that cannot be fully covered by SBS while can be reached by the center MBS. We define these MUEs as $\mathcal{U}_M = [1, 2, \ldots, U_M]$. Over time domain, a micro cell n has various numbers of SUEs at a time slot t. So we define the set of SUEs at time slot t of micro cell n as $U_n(t)$.

In reality, the identical network resources can be reused by multiple SBSs at a specific time slot, therefore the interference between SUEs and SBSs in other micro cells. In this work, we quantize this kind of interference as the signal to interference-plus-noise ratio (SINR) as follows:

$$SINR_{U_n(t)} = \frac{p_n g_n^m}{\sum_{i=1, i \neq n}^{N} x_n^m(t) p_n g_i^m(t) + \sigma^2}, \tag{2}$$

where p_n represents the assigned power to each associated SUE and g_n^m denotes the gain of channel from SBS within micro cell n to the SUE when the resource block (RB) m is reused by multiple UEs. We assume that the channel is an additive-white Gaussian noise (AWGN) channel so σ denotes the variance of AWGN noise. Finally, $x_n^m(t)$ is a Boolean variable indicating whether the RB is assigned to a specific UE. If $x_n^m(t) = 1$, it means that RB m is allocated. $x_n^m(t) = 1$ means RB m is not assigned to any SUE.

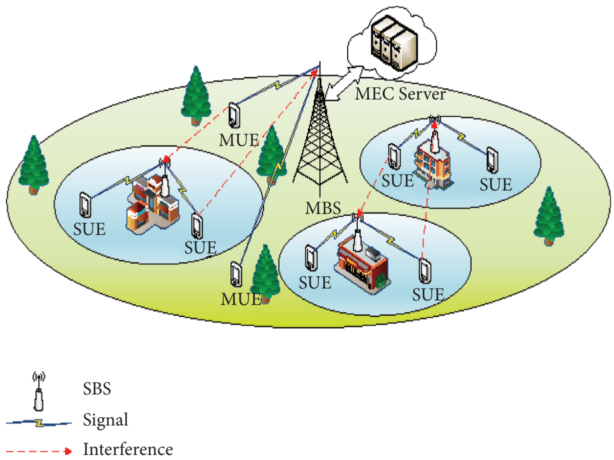

FIGURE 1: An illustration of ultradense network redrawn from [7].

Once we have the metric SINR for each SUE set $U_n(t)$, the summation of overall downlink throughput at a specific time slot t within the micro cell n could be computed based on the following equation:

$$TP_n(t) = \sum_{U_n \in \mathscr{U}_n} TP_{U_n}(t), \tag{3}$$

where $TP_{U_n}(t)$ can be shown as

$$TP_{U_n}(t) = B_m \times log_2\left(1 + SINR_{U_n(t)}\right), \tag{4}$$

where B_m is the bandwidth of the RB m, which is usually fixed for a given RB.

It is more meaningful to consider the total throughput for the whole UDN. Hence, we can calculate the total throughput based on the aforementioned $TP_n(t)$ as follows:

$$TP(t) = \sum_{n=1}^{\mathscr{N}} TP_{U_n}(t). \tag{5}$$

The UDN system not only requires high-speed network throughput but also needs to achieve some levels of efficiency. Apart from the total throughput for the UDN system, the other factors need to be considered are the spectral efficiency (SE) and energy efficiency (EE) for the system. Similar to [5], the SE is denoted as the ratio between the total throughput and the bandwidth of the given UDN at time slot t. In a similar pattern, the EE for this UDN is defined as the ratio between the total throughput and power dissipation at time t. The metrics SE and EE are summarized as follows:

$$\begin{cases} SE(t) = \dfrac{R(t)}{\sum_{i=1}^{M} B_i}, \\[2ex] EE(t) = \dfrac{R(t)}{p_M + \sum_{n=1}^{\mathscr{N}} \sum_{U_n \in \mathscr{U}_n} U_n(t) p_n}, \end{cases} \tag{6}$$

where p_M denotes the power consumption by macro cell network.

The goal of achieving optimal resource allocation for a given UDN is equivalent to maximizing the spectral efficiency SE as well as the energy efficiency EE at the same time. The conventional mobile system adopts various approaches to generate a good resource allocation policy. These algorithms include discrete optimization approaches, convex optimization methods, and other heuristic-based algorithms. However, the feasibility and performance of these previous algorithms heavily depend on the application scenarios. When the communication environment varies, a significant degradation in the quality of resource allocation is observed. Hence, we proposed a novel and efficient deep reinforcement learning algorithm in the following sections.

3. Proposed Efficient Resource Allocation Algorithms for UDN

3.1. Deep Reinforcement Learning. The resource allocation tasks for the UDN system can be regarded as a problem of searching the optimal control sequence that distribute the resource blocks within the UDN. However, the complex communication environment makes it difficult to accurately obtain the optimal allocation strategies that dissipate minimum energy while maintaining high spectral efficiency. To address this problem, similar to [5], we take the advantages of deep Q-learning algorithms [8]. Moreover, we also present optimization schemes to develop computationally efficient models with negligible performance loss.

As shown in Figure 2, for the case of UDN resource allocation task, the MEC server is regarded as an agent that interacts with the macro cell and micro cell environment. The goal of MEC server agent is to maximize the total reward between the first state and the final state. MEC server will make certain decisions that allocate the network resources based on the received data and information from different levels of cellular networks. After the decision is made based on the policy within the agent, the state of the UDN system will be changed and reach to various scenarios defined as state. As the decision (or actions) are taken, the agent receives positive or negative rewards.

Figure 3 depicts the overall diagram of our proposed deep reinforcement learning-based efficient resource allocation scheme for UDN. There are two parts in the depicted figure: training phase and inference phase. For the training phase, we use the system model in Section 2 to emulate the environment of UDN. Once the training phase has been completed, the trained model is optimized via network pruning algorithm to reduce the required model weights and computation complexity. In the following parts, we introduce the development steps of our algorithms in detail, including reward function design, action space design, and network model pruning.

3.1.1. Reward Function Design. The reward function design is a key factor that determines the final quality of resource allocation. This is because the reward function will guide the agent to take actions and make decisions. The actions will impact the state of UDN system. The reward design plays an important role in the task since it determines the quality of resource allocation and intelligence level of trained

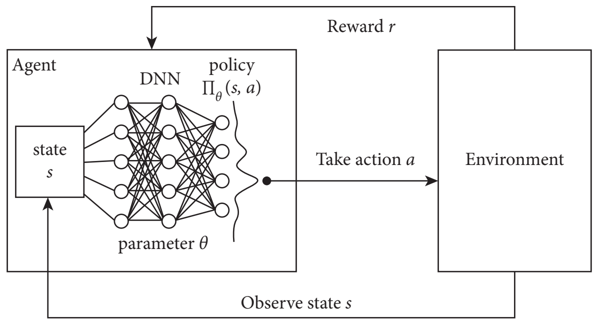

FIGURE 2: Overall diagram of deep reinforcement learning.

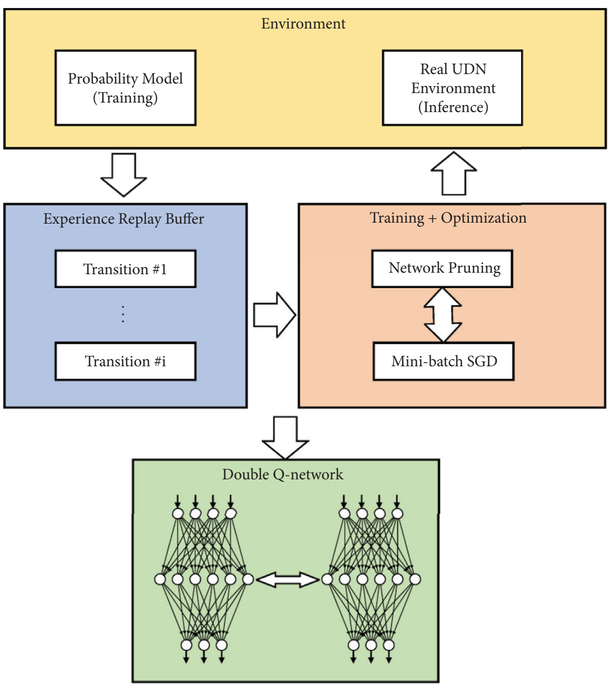

FIGURE 3: Proposed deep reinforcement learning-based efficient resource allocation scheme.

allocation algorithms. The key principle of designing reward function is that the reward should accurately reflect the goal of target application. Here, we adopt the two efficiency metrics, namely spectral efficient SE and energy efficiency EE in equation (6), as the reward function. We make minor modifications by summing these two metrics into one single reward with a weight ε. At a time slot t, the reward function is

$$r(t) = (1-\epsilon)SE(t) + \epsilon EE(t), \tag{7}$$

where the reward function considers both energy consumption and the spectral efficiency. It should be noted that the reward at time t is determined by the current state of network state. If we train the model properly, the agent is able to achieve the optimal reward by balancing the two aspects.

Achieving the optimal reward at time t as equation (7) is not enough since it is not guaranteed that the agent can achieve the global optimal goal. We hope the agent is able to maximize the total reward over a given period of time. In this case, the reward for single time step becomes a cumulative reward function through summing up the received reward at different time steps. The total reward that maximizes the reward between the initial and state becomes:

$$R_{total} = \sum_{t=1}^{T} \beta^t r(t), \tag{8}$$

where R_{total} is the sum of each reward the initial state to the end. In deep reinforcement learning, a discount factor $\beta \in [0, 1]$ is added to weight the different contributions of rewards in short term and long term. Small discount factor β reduces the importance of reward obtained from previous time steps. It is easy to understand that $\beta = 1$ means all the rewards are treated equally.

3.1.2. Action Space. The UDN state of next time step after the control signal is sent by MEC server can be considered to be only determined by the current network states, communication environment, and the resource allocation signals of the UDN. It is independent from the previous states. Hence, the resource allocation policy of UDN can be regarded as the Markov decision process (MDP). The large search space for the action sequence is significantly reduced under the assumption of MDP.

Considering the real realizability of simulation that accommodates real UDN system, we discretize the resource allocation signal of UDN system by a constant time interval. This is because the computing resources in MEC server are limited, thus unable to process data and make resource allocation with very high frequency. Therefore, we assume that the discrete control signal for RBs is in the following form:

$$A = [x_1(t), x_2(t), \ldots, x_T(t)], \tag{9}$$

where the time range of the control signals varies from time step 1 to time step T. It can be seen that the dimension of action space grows linearly as the time steps increases.

3.1.3. Model Updating and Training. Several tricks are used to make the iterative updating and training process more stable. According to [9], since the environment is usually complex, it is not realistic to store all of them into the Q table of traditional reinforcement learning. To alleviate this problem, deep Q-learning uses a deep neural network to estimate the Q-value function. Based on the Bellman equation, the Q-value updating equation is given as

$$\begin{aligned} Q(s_t, a_t) &\leftarrow Q(s_t, a_t) \\ &+ \alpha\left[R_{t+1} + \gamma \max_a Q(s_{t+1}, a) - Q(s_t, a_t)\right], \end{aligned} \tag{10}$$

where $Q(s_t, a_t)$ denotes the Q-value function associated to time step t while α represents the learning rate. Likewise, $Q(s_{t+1}, a)$ is the Q value associated to next time step after the MEC server is taking action a.

The weight of the neural network is initialized using random function. And we define the weight of neural network as w. The weights are updated in an iterative pattern through utilizing the mini-batch stochastic gradient descent (SGD) training algorithms. Specifically, the training of neural networks can be complete through updating the weights with the gradient with respect to the loss function. The updating procedure can be summarized as the following formula:

$$w_{k+1} = w_k - \alpha \cdot \mathbb{E}\Big[R_{t+1} + \gamma \max_a Q\left(s_{t+1}, a; w_k^-\right) \\ -Q\left(s_t, a_t; w_k\right)\Big] \times \nabla_{w_k} Q\left(s_t, a_t; w_k\right), \tag{11}$$

where the weights of target network at the kth iteration are called w_k^-. The weights w_k^- are set to be fixed during the training process and can only be updated using the Q-network weights w_k every C training iterations. The loss function we used in this paper is the mean squared error (MSE) between the target Q value and the output results of neural network.

The updating process in equation (11) for the target network and Q-network may experience some overestimating values of actions by the analysis in [9]. The reason behind this circumstance is that the mentioned scheme uses the same network to calculate both the predicted value and the target value. Hence, it leads to some divergence between the computed results. The overestimation problem hinders the resource allocation algorithms from choosing the good action in some UDN states. As a result, the overall performance of the resource allocation algorithms is negatively impacted. The negative effects arose from overestimating values can be reduced by using two different deep Q-network and target network [9]. In this case, the Q-value function is rewritten as follows:

$$Q\left(s_t, a_t\right) \leftarrow Q\left(s_t, a_t\right) + \alpha\left[R_{t+1} + \gamma Q'\left(s_{t+1}, a\right) - Q\left(s_t, a_t\right)\right], \tag{12}$$

where functions $Q'(\cdot)$ and $a = max_a Q(s_{t+1}, a)$ are used to estimate the expected Q-value by the selected action a that maximizes the value of the predicted Q-value network.

As introduced in [8], the training process for the agent will experience unstable circumstances if we just run the deep Q-learning algorithms on the state-action pairs as they occur during simulation. To equip the agent with some capabilities of memory, we introduce the experience replay buffer to store the transition of discovered data and occurred experience. The experience replay is used to reduce the correlation of observed samples, increasing the robustness of training process. As shown in Figure 3, the experience replay buffer stores the agent's experiences, including taken actions, states, and rewards over a certain time steps.

Exploration and exploitation are the two critical concepts for reinforcement learning. Exploration makes an agent improve the current knowledge about each action, while exploitation is able to select the most rewarded action by exploiting current action-value estimations. To balance the exploration and exploitation, ε-greedy policy is investigated to choose between exploration and exploitation randomly. It can be expressed by the following equation:

$$a_t = \begin{cases} a\, randoaction, with\, probability\, \epsilon, \\ \max_a Q(s, a), with\, probability\, 1 - \epsilon, \end{cases} \tag{13}$$

where the agent tends to select the action that maximizes the current Q-value with probability $1 - \varepsilon$. In contrast, the agent selects a random action with probability ϵ. In other words, the ϵ-greedy policy will let the agent explore most of the time. The larger ϵ value indicates that the control algorithm is more likely to choose a random movement. The value of ϵ cannot be too large since the large ϵ may deteriorate the overall performance. In the contrast, small ϵ value let the agent has a small chance to explore new experience, thus limiting the peak performance. In this paper, ϵ value is selected empirically based on the previous study.

3.2. Model Pruning. The training and inference of fully connected networks are computation-intensive and memory-intensive. Large amounts of computing and memory resources are required to perform the training and inference of deep neural network models. When the MEC server is equipped with limited computing chips, the computationally intensive workload of DNN will become the bottleneck, thus increasing the response time of resource allocation. These problems not only increase the implementation costs but also hinder the deployment of proposed resource allocation algorithms on some resource-constrained MEC servers. To solve this challenge, we use the model pruning methods in [10, 11], which are used to reduce the size of network models by removing redundant connections between fully connected layers.

There exists various types of network pruning algorithms to optimize the neural network structures. The deep compression in [10, 12, 13] is one of the promising methods to optimize sparse neural network architectures. The basic idea of deep compression is progressively searching and removing the redundant weights that have relatively small magnitudes. Figure 4 depicts the neuron connections of original and pruned fully connected layers. The original layer connection is dense and requires large excessive number of weights. Network pruning searches for the most representative and important connections for each layer. Then remove the trivial connections through setting the weights to zero, thereby effectively cutting the weights and reducing the model size as well as computational complexity. After applying the optimizations, the inference of neural network can be accelerated by several times without loss of performance. Meanwhile, the model size will shrink dramatically as large amounts of weights are pruned.

4. Simulation Results

4.1. Experiment Platform and Parameters. We perform simulations and experiments to verify the performance of proposed algorithms. The detailed configurations and process of simulation are given as follows. The proposed deep reinforcement learning algorithms are implemented using the state-of-the-art deep learning library, Pytorch. GPU is

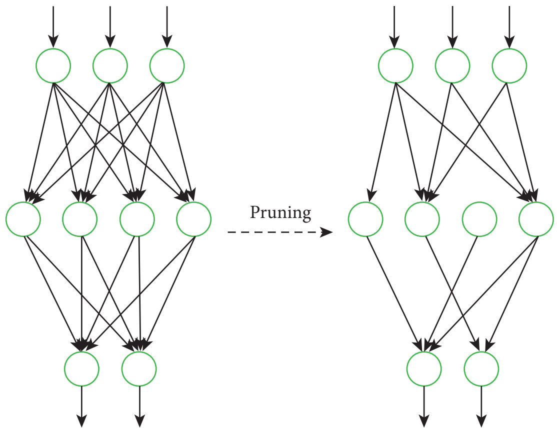

Figure 4: Weight pruning process for original deep neural network.

used to accelerate the training and inference process. The target network and deep Q-network both adopt a five-layer basic structure, where there are 64, 128, 256, 192, 96 neurons for each hidden layer.

During the training process, the mini-batch size is selected as 64 to stabilize the weight updating and achieve a smooth convergence process. The Adam optimizer [14] is used for achieving faster convergence. The input of trained resource allocation algorithm is the vector representing the network state of UDN. Suggested by [8], the probability of ϵ-greedy policy is chosen as 0.05. We create an experience replay memory with a buffer size of 3200. The weights of target network are copied every 5 training iterations. The discount factor of cumulative reward calculation is set to 0.96. The parameters of UDN are similar to those in [5]. The simulation parameters are summarized in Table 1.

Table 1: Summary of simulation parameters.

Parameter	Value
Total bandwidth	20 MHz
Number of RBs	80
Number of time slots	1000
Value of p_M	46 dBm
Batch size, B	64
Discount factor, γ	0.96
Experience replay buffer size, N	3200
Update frequency, C	5
ϵ-Greedy probability	0.05

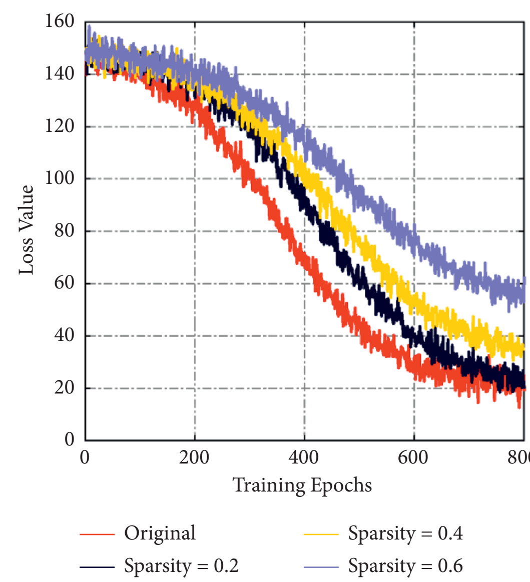

Figure 5: Loss value of DQN under different training epochs.

4.2. Simulation Results. We use the UDN system model to generate multiple training and testing data. We train various models under different weight sparsity constraints as in [10]. For each model, we train the associated model for at least 800 training epochs.

The average loss value of various DQN models for different training epochs is illustrated in Figure 5. As we can see, the loss values of all models decrease as the training epochs increase. The dense model achieves the fastest convergence. The sparse model with sparsity = 0.4 achieves comparable loss value as the dense model. This means that this sparse model is also able to yield promising performance while reducing the weight number and computational complexity by around 60%. The convergence process of model with 60% sparsity is much slower than other models. It can be inferred that the resulting performance is not acceptable.

We also test the yield system efficiency of propose resource allocation schemes under different number of SBSs. The number of SBS ranges from 6 to 18. The results are depicted in Figure 6. It can be seen that the spectral and energy efficiency gradually drops as the number of SBS is

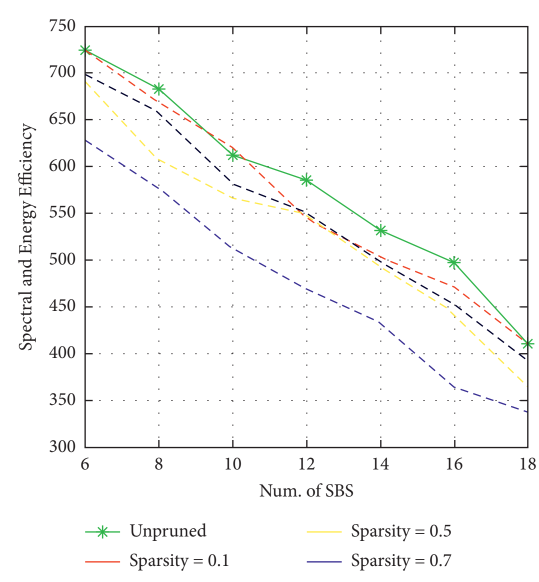

Figure 6: Spectral and energy efficiency under different numbers of SBS.

increasing for all models. We can see that the unpruned model obtains the highest system efficiency. The model with sparsity 50% is able to achieve about 90% efficiency compared to the unpruned baseline. Meanwhile, the total complexity to perform the resource allocation tasks is reduced by 50%. Hence, the weight and model pruning strategies provide a tradeoff between quality of resource allocation and algorithm complexity. For some MEC server that has limited computing resources or heavy workload, we can choose the resource allocation models with more sparsity to make the network resource scheduling more quickly and efficiently.

5. Conclusion

In this paper, we develop and propose the resource allocation algorithms for UDN based on deep reinforcement learning. First, we introduce the resource allocation strategies in MEC server based on double deep Q-learning. Then, to meet the requirements of low latency and limited cost, we optimize the algorithm by pruning redundant model weights and making a tradeoff between computational complexity and performance. The experiment and simulation results show the gain and effectiveness of proposed algorithms. Our proposed approach can be applied to UDN resource allocation in the 5G system, especially when the computing power is limited. The future work will focus on considering more impacting factors of UDN into this framework.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Exploration of the Construction Model of School-Business Collaboration System in Vocational Colleges Based on Information Resource Sharing

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The exchange of literature and information resources between higher vocational colleges and cooperative enterprises is a win-win situation in which both parties benefit. Collaboration between schools and businesses is a significant departure from the traditional vocational education model, as well as an innovation in the talent training model, an important direction of higher vocational education reform, and the focal point for the formation of vocational education characteristics. Collaboration between schools and businesses is now not only an effective way for businesses to train a large number of applied technical talents, but also an effective way for vocational colleges to change their disciplinary structure. At the same time, collaboration between schools and businesses is critical to the advancement of vocational education. The focus of this article is on the publication of literature on the long-term mechanism of school-business collaboration, the field of research on the long-term mechanism of school-business collaboration, state laws and regulations on school-business collaboration, and academic opinions. The content, mode, problems to be solved, and importance of sharing document information resources in school-business collaboration are the main topics of this article. Vocational technical colleges and businesses should benefit from each other and maximize their respective advantages in school-business collaboration. One of the greatest advantages of higher vocational colleges is the abundance of literature and information resources. This article will raise a key question through a review of the literature: how can you establish an effective long-term mechanism for school-business collaboration? This theory has been enhanced by previous research in order to put the issue of school-business collaboration into practice and provide theoretical and practical guidance that will benefit the country, society, schools, and, most importantly, student employment.

1. Introduction

Vocational education cannot become vocational education in the true sense without the participation of enterprises. Only the close cooperation between schools and enterprises can fundamentally realize the authenticity of the training teaching environment, facilities and methods, the duality of students' roles, and the training of teachers, the dual-teacher nature, the mutual benefit of education funding (enterprise training funding-government investment funding), the security of systems and information, and so on. How to realize the sharing and optimal allocation of educational resources and achieve the goal of mutual assistance, mutual benefit, and win-win in school-business collaboration is a topic of common concern and discussion among all sectors of society [1]. School-business collaboration is an innovative model for schools and enterprises to cultivate and accept talents. In a practical sense, on the one hand, it can solve the employment problem of students and reduce employment pressure; on the other hand, this method can solve the problem of shortage of talents in enterprises. It can be seen that a successful school-business collaboration will undoubtedly become a win-win model for the development of schools, enterprises, individual students, and society.

The way of school-business collaboration is conducive to the adjustment of local economy, is conducive to the transformation of scientific and technological achievements into actual productivity, and is more conducive to driving the adjustment of local economy, thereby promoting the prosperity and development of local economy. Relatively speaking, in the process of school-business collaboration in running schools, the enterprise is the main body of the cooperation, and the enterprise pays more [2]. Accepting students for internships will add additional burden to the factory, also taking responsibility [3]. Higher vocational colleges are relatively in the secondary side and need to find companies everywhere to cooperate, seeking companies to receive student training and internships [4].

To some extent, the provision mode of information resource sharing can bridge this gap. Because higher vocational colleges are the primary parties and instructors in the sharing of literature and information resources, they can proactively provide literature and information services to businesses, assist businesses in developing joint information resources, and benefit businesses. More literature information resources are required for the development of related cooperative enterprises or the ability to accept more students [5]. For mutual benefit and mutual benefit, both schools and businesses can make full use of literature and information resources. Enterprises can save a portion of their manpower, material resources, and financial resources by reducing unnecessary document duplication. Both sides can benefit from each other, complement each other, and grow together, bringing the two parties' cooperation relationship closer together. Simultaneously, through information resource sharing and cooperation, all types of enterprise information can be fed back to higher vocational colleges in a timely manner, facilitating the adjustment of professional directions or enrollment plans, the organization of training projects, and the implementation of employment indicators for higher vocational colleges. Colleges and universities use an order-style approach to talent development [6].

In the school-business collaboration, the key point is how to establish a sharing mechanism between the school and the enterprise, so that both parties can make full use of the literature and information resources, communicate with each other, maintain a close relationship, and obtain what they need to achieve a win-win goal. System guarantee for the sharing of literature information resources in school-business collaboration [7] includes centering on the library of the higher vocational college, providing rules and regulations for the use of literature and information resources, rules and regulations for the use of school-enterprise network resources, funding and sharing system for information resource development and sharing, and the internal construction and development of libraries in higher vocational colleges., where the library should do a good job in the integration of document information resources and highlight key majors in accordance with the professional settings of the hospital. According to the needs of cooperative enterprises, production and R&D projects expand the collection of relevant professional and project literature and information, highlighting local characteristics [8].

2. Related Work

School-business collaboration plays an important role in improving the technological competitiveness of enterprises and expanding their technological resources. School-business collaboration has also accelerated the process of marketization of new technologies. Universities and enterprises at home and abroad are constantly conducting research and practice to explore better school-business collaboration models. Therefore, a key issue in the study of school-business collaboration is how to scientifically and effectively evaluate school-business collaboration projects.

According to [9], higher vocational colleges' financial investment is insufficient, and the conditions for running schools, particularly experimental training conditions, are relatively weak: The school-business collaboration mechanism is not perfect; the cooperation has not yet established a fixed base for industry-university-research cooperation; theoretical research on school-business collaboration in higher vocational education lags behind. According to [10], vocational education still has issues such as a lack of social recognition, a backward professional setting, and an unreasonable curriculum setting; key points and teaching difficulties are not prominent; and practical links are severely lacking. School-business collaboration, according to [11], is beneficial to resolving the supply and demand of talents between schools and businesses; it is beneficial to accurately positioning the goals of higher vocational education; it is beneficial to broadening the employment channels for students in higher vocational colleges; and it is beneficial to the formation of higher vocational colleges, the characteristics of a school principal. The difference is that [12] also suggested that collaborating between schools and businesses can significantly improve the conditions for running schools in higher vocational colleges. According to [13], school-business collaboration is also conducive to educational reform and talent training model reform; it is conducive to enterprise participation in the school talent training plan and process, as well as deepening the teaching reform; it is conducive to enterprises mobilizing their enthusiasm and initiative to run schools. In the course of running a school, we will make full use of the enterprise's human and material resources. Literature [14] based on the analysis of school-business collaboration model, guaranteed mechanism, monitoring, and evaluation mechanism and gave a set of evaluation index system for the quality of school-business collaboration. This achievement has important reference significance in enriching the theoretical system structure of higher education evaluation, improving the school-enterprise cooperative education and teaching quality evaluation system, and improving and ensuring the quality of education and teaching in schools. Literature [15] studied the research and practice of the school-business collaboration talent training model in higher vocational colleges. The development, change, and evaluation of the relationship between colleges and enterprises have gradually become the focus of researchers and the main concerns of practitioners. On the basis of the research of resource dependence theory, the effectiveness of cooperation between the two parties and the degree of resource dependence and difficulty establish a stable degree of influence. The relationship between the dependence structure of teaching management, analysis, and discussion shows that the impact of school-business collaboration is not only the relationship with teaching management, the degree of dependence on resources of the two parties' symbiosis, and the relationship with cooperation; the influencing factors are far greater than the degree of dependence on resources. Literature [16] aimed at the goal of talent training in higher vocational colleges, constructed a basic school-business collaboration teaching quality evaluation system with diversified subjects such as schools and enterprises (industry, employers), and demonstrated the diversified subjects and diversified subjects of teaching quality evaluation, with the choice of the evaluation method and the determination of diversified evaluation items. Literature [17] pointed out that the development of modern higher vocational education will inevitably promote cooperative education between schools and enterprises. Constructing a scientific and objective evaluation system for school-business collaboration will provide strong support and reference for the smooth development of school-business collaboration. Wang Ning put forward his own ideas on the construction of the evaluation system of school-business collaboration in higher vocational education.

For most companies, they do not evaluate success based on the financial benefits of cooperative research and development management or the number of research results. In order of importance, success is achieved by cooperation between companies that achieve the following goals: increase the understanding of new technologies and new technologies; provide employees with opportunities to acquire new knowledge; improve strategic thinking; obtain well-trained employees and knowledge of more access to property rights, improved corporate credibility, and better employee recruitment.

Literature [18] overviews the research in recent years; often it is the school's keen interest in school-business collaboration and the combination of work and learning that make the school-business collaboration a bottleneck. The primary issue is that collaboration begins only from the perspective of the school, ignoring the feelings of the enterprise, emphasizing the enterprise's public welfare and social duty, and ignoring the enterprise's needs. To break through this bottleneck, it is necessary to think about the composition of the performance evaluation index of the combination of work and study based on the perspective of corporate interests. Higher vocational education cultivates talents that directly benefit business and industry, while cooperative colleges and universities cultivate talents that directly or indirectly benefit business, allowing school-business collaboration to grow in depth and breadth and be long-lasting and smooth. China's higher vocational education has achieved "school-business collaboration, work-study integration," according to [19]. Although some progress has been made, a long-term operating mechanism and a complete system have yet to be established. In the implementation process, there are still some issues to be resolved in the use of the School-Business Collaboration Talent Training Model. It is difficult to overcome the traditional closed teaching quality monitoring system. We must improve teaching quality evaluation to adapt to the open system of higher vocational education talent training model of "school-business collaboration, work-study integration." There are also studies that use specific data as a basis for evaluating school-business collaboration through the creation of data models. For example, [20] shows that the overall level of cooperation between financial vocational schools and enterprises is relatively low, based on principal component analysis and empirical analysis of seven types of finance and economics on the performance of higher vocational school-business collaboration. There is a significant disparity between the two, as well as an imbalance; the success of school-business collaboration is dependent on the cooperation, process, and impact of school and enterprise resources. The two decisive factors are that we must place a high value on enterprise participation. As soon as possible, a multichannel and multidirectional exploration of school-business collaboration methods strengthen interschool cooperation and strengthen the radiation model and the leading role of key universities should be included in relevant local laws and regulations.

For the evaluation of the effect of school-business collaboration, two aspects are involved in the specific implementation process, namely, the establishment of the effect evaluation index system and the implementation of the effect evaluation. This article will discuss and determine the index system for evaluating the effectiveness of school-business collaboration projects through methods such as literature review, research, interviews, and specific school-business collaboration projects. Then the use of the evaluation index system should cover the effects of school-business collaboration projects in the tripartite of enterprises, universities, and the government.

3. Document Information Resource Sharing in School-Business Collaboration Forms Complementary Advantages

In the school-business collaboration, the advantage of the enterprise lies in the fact that the enterprise can provide students in higher vocational colleges with internship places, training, and employment opportunities. Enterprises have advantages in equipment resources. It can be used by students for practical operation. The enterprise has advantages in production technology and industry, and its personnel can guide students on-site, so that students can master certain skills. The company also provides job opportunities, so that some of the students can stay in for employment. The disadvantage is that companies mainly consider problems from economic benefits or are affected by economic operating cycles and are unwilling to invest funds in the construction of literature and information resources. Some enterprises are biased towards short-term behaviors, lack long-term benchmarks, and do not pay attention to the construction of literature and information resources at all. Enterprises lack professional management personnel of document information, which also affects the construction of document information resources [21].

Rich books and literature information resources, a certain amount of storage, and the formation of a library-centered literature information resource database are all advantages of higher vocational colleges. Have professional personnel who are involved in the collection and use of literature information and materials, as well as specific work experience. Take advantage of technical theoretical advantages in computer and network technology applications. Relevant professional teachers and skilled teachers are available. They have a certain theoretical and practical level of knowledge, a better understanding of the state of development of a particular industry and profession, and guiding advantages in certain professions and industries. The disadvantage of higher vocational colleges stems from the fact that college operation management differs from enterprise operation management. It is easy to cause information uncertainty because it does not fully comprehend the actual situation of enterprise literature information needs. Higher vocational colleges have strict school funding management and limited funds, making larger projects difficult. Figure 1 depicts the talent development model.

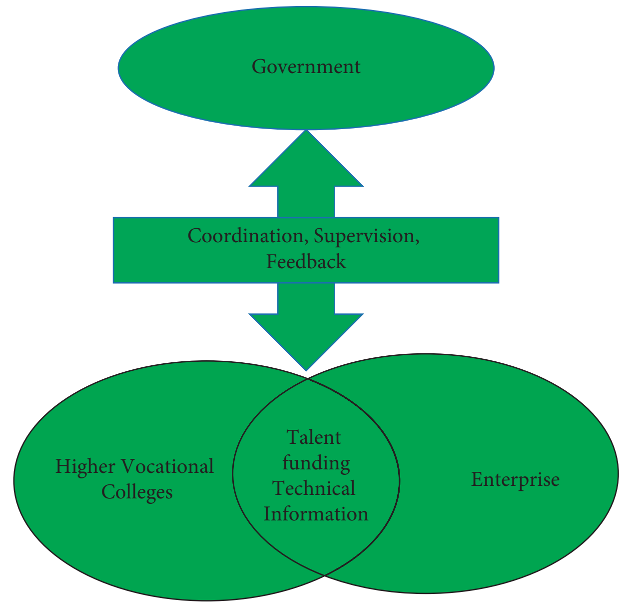

Figure 1: Talent training model.

In Figure 1, higher vocational colleges and enterprises share resources such as talents, technology, information, and funds. The government supervises and coordinates their cooperation and constantly makes adjustments based on their feedback information to ensure smooth cooperation.

Higher vocational education necessitates a close relationship between schools and businesses. Vocational schools collaborate with businesses and serve them in order to gain their support, assistance, and participation in order to expand their development space. In our country, there is currently a significant disconnect between higher vocational education and the business community. Enterprises are not overly enthusiastic about participating in higher vocational education. Disconnection between theoretical and practical teaching is a common problem in higher vocational colleges. The government must be involved in solving these issues. To realize the sharing of educational resources, Taiwan should follow the path of school-business collaboration and school-school cooperation in running schools and establish vocational education groups based on the principles of equality, voluntariness, mutual benefit, and common development. Form a school-business collaboration group school structure in which the school provides teaching management sites and basic theory teachers, while the enterprises provide equipment, technology, internship training bases, part-time teachers, and job opportunities.

4. Platform Design and Implementation

The school-business collaboration professional teaching system of information resource sharing highlights the benign interaction of the school-business collaboration behavior. It is a concise and quite operable theoretical framework of teaching structure. Compared with other teaching modes, it also consists of four elements: theoretical basis, functional goals, realization conditions, and activity procedures. Cultivate vocational technical personnel and high-quality laborers with dialectical materialist worldview, outlook on life and good professional ethics, and being capable of serving the front line of production. It is necessary to attach importance to the mastery of basic cultural and professional knowledge of students, but also to emphasize the cultivation of professional practical skills. At the same time, in accordance with the industrial characteristics of the cluster economy and the skill requirements of the industrial post group, vocational and technical personnel with intermediate and primary operating skills are trained. Make full use of the human, information, and material resources provided by modern enterprises and combine the characteristics of vocational education to conduct professional teaching. At the same time, it is necessary to achieve the necessary conditions for the benign interaction between the school and the enterprise in cooperation concepts, teaching training, and technology research and development. The details are shown in Figure 2.

The traditional teaching mode is frequently limited to the school's professional theory teaching in the activity procedure and rarely includes the teaching of corporate job group professional skills. The professional teaching model of information resource sharing for school-business collaboration includes not only the theoretical teaching of professional courses in the school, but also the teaching of professional skills and enterprise job skills training [22]. At the same time, the two parties' friendly interaction is the behavior that runs throughout the entire program. As one of the primary pillars of school-business collaboration, the school should fully implement the college's guidance on students' ideological behavior and the development of a sound personality and continuously improve its own school-running level with the help of industry and enterprise resources. Enterprises should actively participate in the process of educating people, extensively participating in all stages of student training, sharing resources, complementing

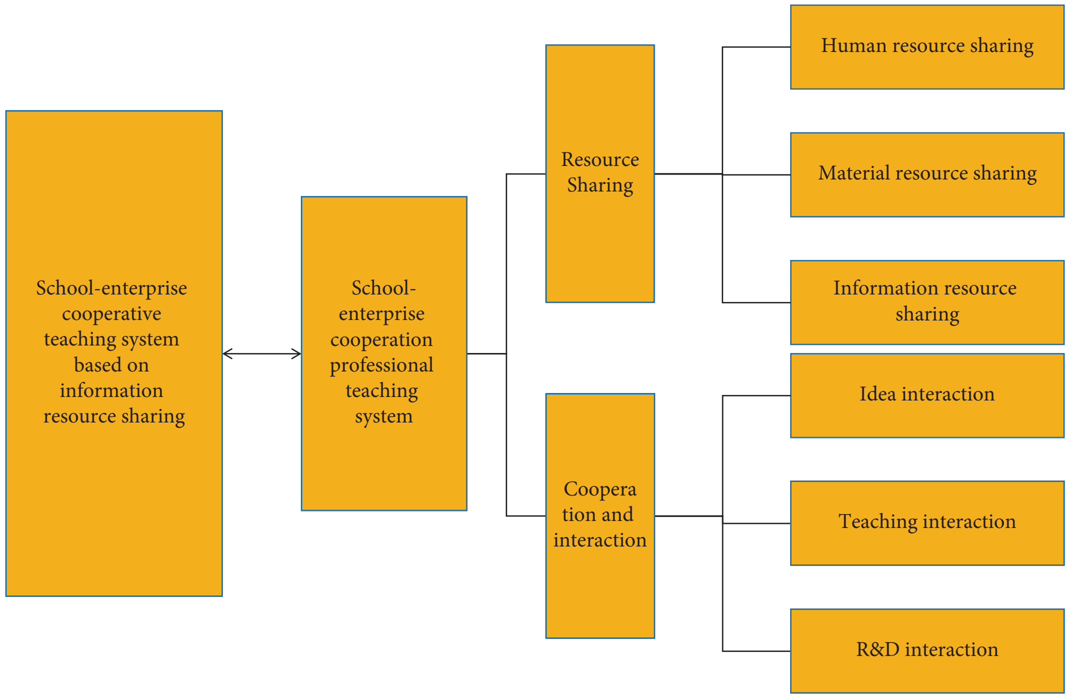

Figure 2: The basic framework of a school-business collaboration professional teaching system based on information resource sharing.

each other's advantages, educating people through science and technology, and technological innovation, achieving corporate profitability and social responsibility, as well as self-development and development, as another important subject of educating people. Industrial development has a high degree of coherence.

5. Research on the Importance of Factors Influencing Enterprise Innovation and Entrepreneurship Based on Information Resource Sharing

5.1. School Evaluation Index Selection. Higher vocational colleges can use the tangible assets of enterprises to provide students with internship places. The training goal of higher vocational education is that talents must have strong technical application ability and strong professional quality. This requires higher vocational education to pay special attention to practical teaching links. There are some experiences and contingency methods that cannot be taught in the classroom. It is possible to be sure of repeated training in a real live environment. Under the current situation where education investment is generally insufficient, it is difficult for schools to provide on-site environments, i.e., internships and training bases, and there is no need to set up a factory for each major as a training place for students. With the support of enterprises, vocational colleges can obtain experimental equipment funding or establish professional practice bases, improve teaching facilities or provide good conditions for practical training, and provide hardware guarantees for cultivating talents.

In order to understand the binary subclassification problem between class j and class k and maximize the boundary between the information resource sharing data, the soft-margin objective function is shown in (1) and (2).

$$\min \quad w_j w_k = \left\| w_j - w_k \right\| \frac{1}{2} + c \sum_{y_i \in \{j,k\}} \xi_i^{jk}, \tag{1}$$

$$y_i^{jk} f_{jk}(x_i) \geq 1 - \xi_i^{jk}. \tag{2}$$

Among them, $xi \in Rd$; ξ_i^{jk} is nonnegative slack variables used to deal with nonlinear data classification problems; assuming that there are a total of c attributes, then there are a total of $c(c-1)/2$ binary subclassification problems. An information resource sharing model is shown in formulas (3) and (4):

$$\min \quad w_j w_k = \frac{1}{2} \sum_{j=1}^{c-1} \sum_{k=j+1}^{c} \left\| w_j - w_k \right\|_2^2 + c \sum_{j=1}^{c-1} \sum_{k=j+1}^{c} \sum_{y_i \in |j,k|} \xi_i^{jk}, \tag{3}$$

$$y_i^{jk} f_{jk}(x_i) \geq 1 - \xi_i^{jk}. \tag{4}$$

When using model (2) to classify the samples, a voting mechanism is used; More categories Ij satisfy the relation. Finally, the predicted category of the sample will get the highest number of votes, as shown in formula (5).

$$\tilde{y}_i = \arg\max_j w_j^T x_i + b_i. \tag{5}$$

Table 1: Analysis results of factors affecting information resource sharing school-business collaboration.

	Dependency	Predictive correlation	Maximum sample dependence probability
Government policy support (GPS)	Higher	Higher	0.732
School entrepreneurship support (SES)	Higher	High	0.876
School's innovation support (SIS)	Higher	Higher	0.762
Enterprise's support for entrepreneurship (ESE)	High	Very high	0.951
Education (EDU)	Higher	Higher	0.769
Participation in the internship (PTI)	Middle	Lower	0.603
Individual ability (IAB)	High	High	0.944
Awareness of entrepreneurial risk (AER)	Higher	High	0.892
Entrepreneurial motivation (EMO)	Higher	Higher	0.824
Entrepreneurial determination (EDE)	Higher	Higher	0.798

In order to verify the effectiveness of the proposed model, the entrepreneurial data in [23, 24] is used as the data sample. The influencing factors considered for information resource sharing are shown in the first column of Table 1. There are five categories of influencing factors: low, low, medium, high, and high. The information resource sharing of model (2) is applied to the sample data, and the specific results are shown in Table 1.

The success of students' innovation and entrepreneurship depends heavily on the support of schools and enterprises to innovation and entrepreneurship. The experimental results in Figure 3 show that the model of school-business collaboration based on information resource sharing is conducive to promoting college students' innovation and entrepreneurship.

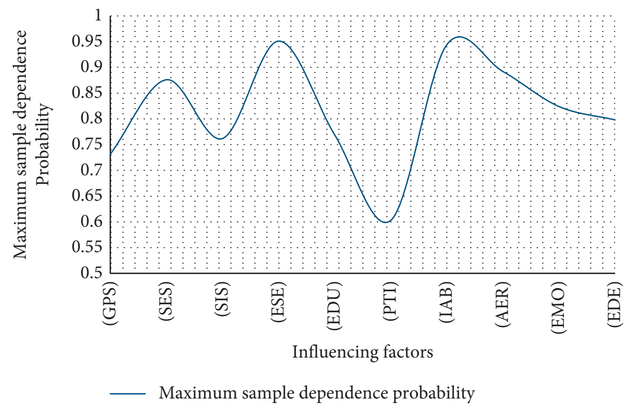

Figure 3: Analysis results of factors affecting information resource sharing school-business collaboration.

5.2. Selection of Enterprise Evaluation Index. The success of school-business collaboration projects for businesses is measured not only in terms of financial gains, but also in terms of scientific research and development progress. The ability to maintain a leading position in technology; the ability to increase training opportunities for corporate employees; the richness of human resource reserves; the improvement of the corporate reputation, and so on are all factors that influence the success of school-business collaboration for businesses. Students who stay in the company as part of the school-business collaboration project can save the company money on recruitment, training, and other costs by providing qualified employees who meet the company's needs directly. In summary, the following evaluation indicators were chosen for the school-business collaboration project: Corporate: corporate reputation, financial income, employee training, and student acceptance or recommendation for employment: work ability, professional characteristics, and competitiveness.

Construct a judgment matrix. For the indicators to be investigated in the target layer and the criterion layer, the average scores of the experts on the indicators are calculated to construct a matrix table. There are two calculation methods: geometric average method and standardized column average method. Calculate the consistency check coefficient C.R. and make a judgment:

$$C.R. = \frac{C.I.}{R.I.}. \tag{6}$$

When $C.R. < 0.1$, it is considered that the consistency of the judgment matrix is acceptable; when $C.R. > 0.1$, it is considered that the judgment matrix does not meet the consistency requirements, and the judgment matrix needs to be revised. The average random consistency index of the matrix is shown in Figure 4.

Calculate the weights between the criteria under the target layer. First, average the scores of the experts and the structure is shown in Table 2 and Figure 5.

Consistency check $C.I. = (\lambda\max - n/n - 1) = (5.195 - 5/5 - 1) = 0.5$. So the judgment matrix passed the one-time test.

5.3. Single-Level Evaluation of the Effects of School-Business Collaboration Projects. The overall effect of school-business collaboration projects is evaluated in this article using a fuzzy analytic hierarchy process. This evaluation method, which combines the two methods, can not only compare the important lines of the evaluation indicators of the school-business collaboration project, but also quantitatively reflect the overall effect of the school-business collaboration project, which improves the project's effect. Aspects can provide a more focused foundation. A judging group is chosen from among the project participants or benefiting personnel from schools, businesses, and governments in this paper. Based on the connotation of each evaluation index,

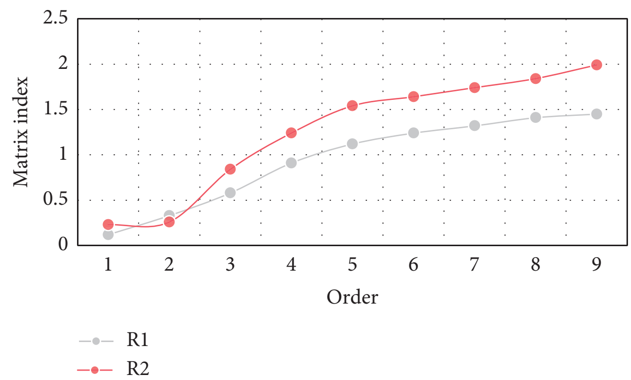

Figure 4: The average random consistency index of the matrix.

Table 2: The structure of the judgment matrix.

Level a	A1	A2	A3	A4	A5
B1	1	0.25	0.261	0.778	4.333
B2	4	1	1.833	5.667	7.333
B3	3.383	0.545	1	4	6
B4	1.286	0.176	0.25	1	3.667
B5	0.231	0.136	0.167	0.273	1

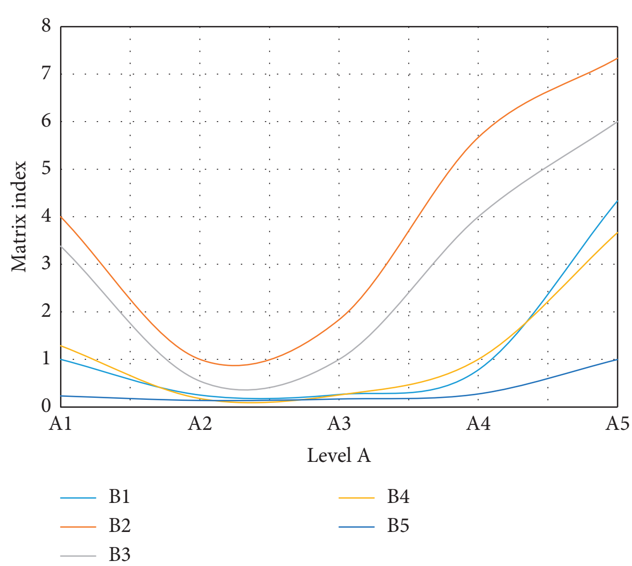

Figure 5: The structure of the judgment matrix.

the judging group will vote on a set of comments. Table 3 and Figure 6 are the statistical process for voting results.

After weighting the weights of each indicator at the scheme layer and the weight of each indicator at the criterion layer, the total ranking weight of each indicator at the scheme layer is obtained. The total ranking of the indicators at the scheme layer is as follows:

From Figure 7, Figure 8, Figure 9, Figure 10, and Figure 11, the fuzzy matrix between the school-business collaboration project effect A and the comment set v can be obtained from the single-level evaluation result of the school-business collaboration project effect. The effect of enterprise-enterprise cooperation projects is good, 22.5% of people think that the effect of school-business collaboration projects is average, and 9.4% of people think that the effect of school-business collaboration projects is very poor. During the operation of the project, the focus of both parties is mostly on strengthening the training of students through various means, in order to enhance students' professional ability and employment competitiveness. For the project itself, it is easier for this approach to obtain a more obvious effect. However, from the perspective of the development of the school, only through the school-business collaboration project to promote the improvement of the teacher's level

Table 3: Relationship between criterion level and program level.

Teacher improvement B1	Teacher training C11 Academic research promotion C12
Student training B2	Training cost C21 Curriculum effectiveness C22 Professional recognition C23 Core competence value-added C24 Graduation design quality C25
Student employment B3	Career planning awareness C31 Employment rate C32 Professional relevance C33 Occupational brother at coincidence degree C34 Value-added professionalism C35
Enterprise B4	Corporate reputation C41 Financial income C42 Staff training C43 Working ability C44 Professional characteristics and competitiveness C45
Government B5	Employment area C51 Income level C52 Current satisfaction C53 Non-unemployment rate C54

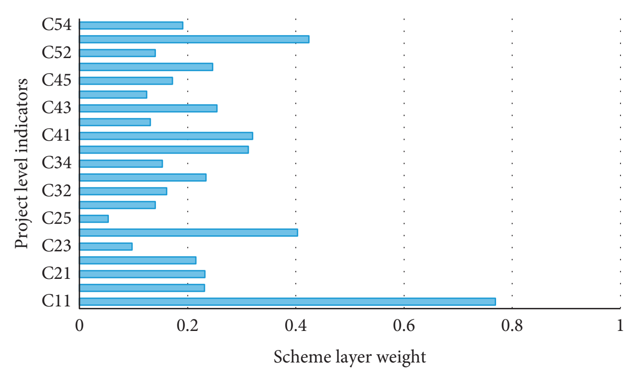

Figure 6: The weight index of the scheme layer.

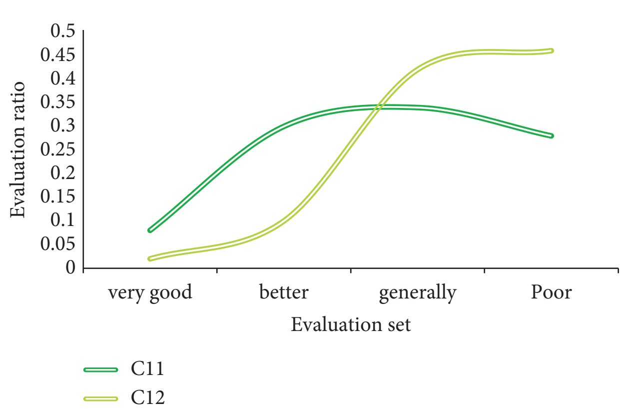

Figure 7: The ratio of teachers to improve B1 evaluation.

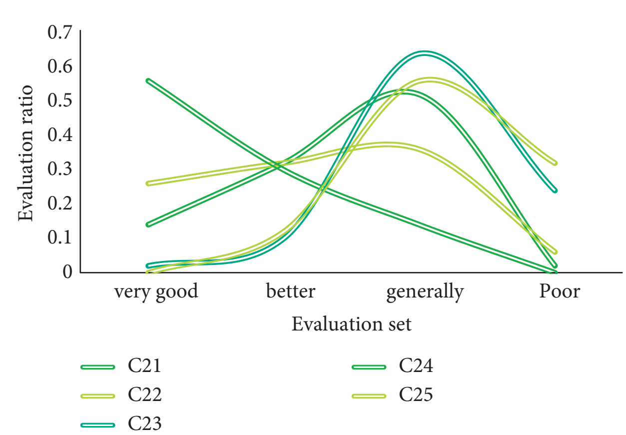

Figure 8: B2 evaluation ratio of student training.

can the theoretical knowledge mastered by the teacher be better combined with the actual production, and the teacher with the "double-qualified" quality can be cultivated. The improvement of quality has cultivated more students with practical ability for schools and society and cultivated more employees with excellent professionalism for enterprises to promote the reform of teaching.

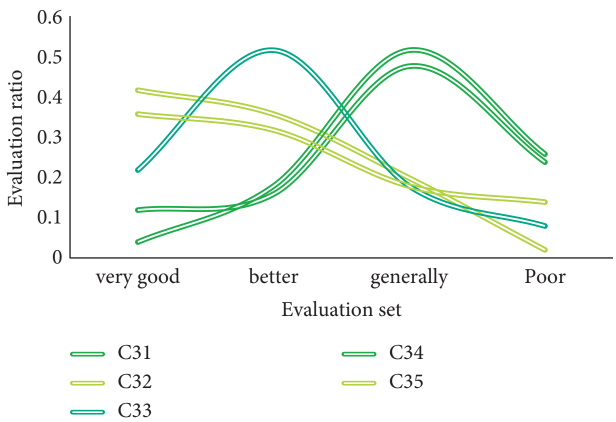

Figure 9: B3 evaluation ratio of student employment.

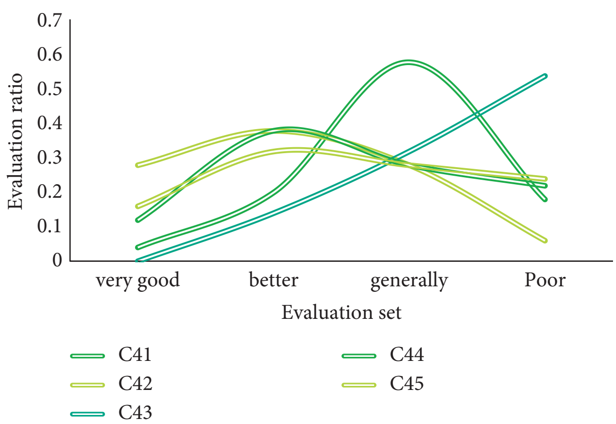

Figure 10: Evaluation ratio of enterprise B4.

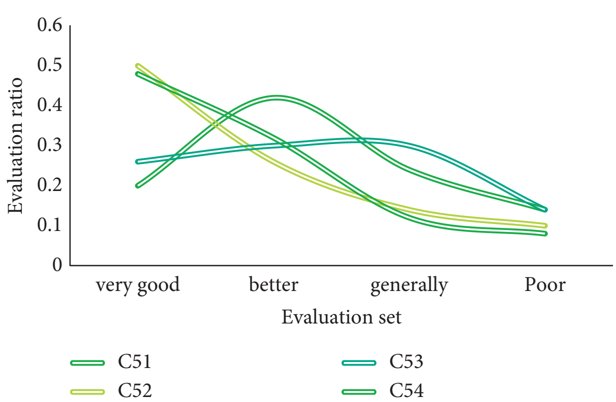

Figure 11: Proportion of government B5 evaluation.

6. Conclusions

This article provides a three-tier school-business collaboration organization system to provide school-business collaboration organization guarantees to ensure the effective implementation of school-business collaboration; four school-business collaboration operating mechanisms provide school-business collaboration system guarantees to ensure efficient school-business collaboration. Operation: Three school-business collaboration groups are formed to provide school-business collaboration in running schools and to integrate high-quality resources for school-business collaboration. It established a hierarchical structure model with five dimensions of teacher improvement, student training, student employment, enterprise, and government as the criterion layer and selected 21 indicators covering the above five dimensions as the program layer and used the analytic hierarchy process to pass on the school. Experts from the three aspects of enterprise and government have calculated the weights of each indicator of the model. The weights are ranked from high to low for student training, student employment, teacher promotion, enterprise, and government.

The largest collection of transaction costs, such as manpower, financial resources, resources, and technology, is the common benefit of collaborative education for all parties involved in the collaboration. Only by actively undertaking their due obligations in collaborative education, actively fulfilling their responsibilities for educating people in various roles, and working closely together and committing to the cultivation of students can the coordinated development of the regional industrial economy, and ultimately the mutual benefit of multiple parties, be realized. The government should exercise its macrocontrol and supervision functions, provide policy support and social guidance for school-business collaboration, and create a system for third-party industry association evaluation. Mechanisms ensure coordinated efforts, with each party fulfilling its responsibilities, as well as multiparty interaction, in order to cultivate high-quality, compound, and practical talents that truly serve the development of regional industrial economies, as well as to achieve sound and rapid vocational education development. Only by resolving the incentive mechanism of school-business collaboration, that is, by paying attention to the short- and long-term interests of enterprises in the process of vocational education, can we attract enterprises to participate in school-business collaboration and form a stable school-business collaboration mechanism, establishing a long-term partnership between schools and businesses.

This article examines the positive effects of school-business collaboration in today's society by looking at the history of the collaboration and the mode of cooperation. Research is even more important. The government's role in school-business collaboration is frequently overlooked in current research. This article begins with a systematic assessment of the impact of school-business collaboration projects from the three perspectives of universities, businesses, and government and ends with an empirical analysis of the experience and shortcomings of school-business collaboration in order to provide school-business collaboration.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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Research Article

Construction of College English Data Resources and Change of Teacher Positioning Using QoS Constraints

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Cultivating students' autonomous learning abilities has become a research hotspot in CE (College English) reform, and the new CE autonomous learning teaching mode with students at the center also requires teachers to change traditional teaching ideas. The traditional teaching mode and teacher orientation have changed dramatically as a result of the new situation of CE teaching reform. The design and implementation of a CE data resource base based on a web database demonstrates that these technologies provide people with greater convenience and practicality. A GA (Genetic Algorithm) based on a QoS (Quality of Service) constraint is proposed on this basis. This algorithm can find a suitable resource node in the computing resources for each subtask that meets the constraint conditions and assign it to the corresponding task. Information-based education has become a powerful driving force for educational revolution, with computer technology and network information technology making English classroom teaching richer, more flexible in form, rich in content, and searchable in data.

1. Introduction

The traditional teaching model has been greatly impacted and challenged as CE teaching reform continues to progress. The reform entails gradually transitioning from a teacher-centered teaching mode of imparting language knowledge and skills to a student-centered teaching mode that emphasizes the development of students' practical language use ability and autonomy in learning. This necessitates a shift in teachers' responsibilities. CE teachers face an urgent problem: how to fully utilize students' initiative of autonomous learning and make better use of the autonomous learning mode to improve their English level. Outside of the classroom, students can learn English in a variety of ways, and the popularity of multimedia teaching in college classrooms has changed CE (College English) teachers' requirements and orientation [1, 2]. The design and implementation of a web-based CE data resource database, on the other hand, can not only realize the educational era's development but also promote network technology's development.

Make full use of social resources and use the "bringing in" method [3]. Good resources should be kept in the teaching resource pool, while outdated and obsolete resources should be discarded. The construction of a professional teaching resource pool should follow the education and teaching philosophy of "putting students' needs first and teachers second" and give full consideration to the characteristics and benefits of teaching resource pools [4]. Text, pictures, animation, and other forms of traditional learning resources can no longer meet the learning needs of learners. When streaming media technology is used to create a large number of audio and video resources, the teaching effect becomes more vivid and vivid [5, 6]. Teachers should play an important role in the learning process by guiding students' autonomous learning activities, assisting students in mastering the proper learning methods, adjusting their learning progress according to their current situation, and setting personalized learning goals. English teachers should also assist students in gathering a variety of learning materials, organizing and analyzing them on a regular basis, and finally assisting students in developing the ability to learn independently [7]. Multimedia web teaching is not only simple and quick, but can also improve teachers' teaching quality while also ensuring teachers' and students' access to resources is reliable. The use of multimedia network teaching can greatly aid teachers in improving teaching quality, allowing teachers to improve their own teaching level to some extent [8].

In the case of emphasizing multimedia teaching, instead of seriously studying the characteristics of multimedia teaching, just emphasize the convergence of forms, which leads to the phenomenon of full teaching in multimedia classroom. The teaching methods of some teachers are not standardized, and the main points are not highlighted. Teachers only demonstrate and read multimedia courseware in multimedia teaching so that students can copy their teaching materials. Multimedia instruction is information-rich, fast-paced, and ever-changing. Students believe that, in the process of multimedia teaching, they are unable to grasp key points and have a strong memory and that it is difficult to digest what is said in class and take notes. As a result, this paper develops and implements a web-based CE data resource database. The platform of the CE data resource database and the teaching resources in the CE data resource database are divided into two sections.

2. Related Work

According to [9, 10], despite the fact that the construction of digital resources has reached a pinnacle, the overall quality is not high, and quality resources are limited; particularly the supply and service based on digital resources are too rough and crazy. In the compulsory education stage, [11] proposes the creation of "synchronous courses for famous teachers," which provides primary and secondary school students with courses from all grades and disciplines in the form of online video, further enriching the supply of quality education resources. Reference [12] has created a multimedia education resource database system with significant communication value. Users of such a network platform of teaching resources can share all types of teaching materials without being constrained by time or geography, and it provides a convenient and quick platform for teaching. According to [13], an English curriculum requires students to cultivate their daily communicative activities in addition to having good language skills. According to [14], English teachers should not only teach students basic English skills, but also consider their psychological well-being and promote their physical and mental development. According to [15], the new teaching model can provide students with rich, vivid, and intuitive information, expand students' cognitive space, shorten students' cognitive process, create a communication bridge, and help students improve their language and cultural awareness.

People's network dreams are embodied in the cloud computing vision. To some extent, distributed computing and grid computing reflect the concept of cloud computing, that is, combining idle resources distributed across a network to provide powerful computing power [16]. Many researchers have tried to use the resource scheduling algorithm in a grid environment to see if resource scheduling in the cloud is possible. In a distributed environment such as a grid, for resource scheduling, [17] describes a task scheduling algorithm for grid computing based on GA (Genetic Algorithm), which aims to maximize resource utilization and throughput. Reference [18] examines existing cloud computing platform solutions and technologies, then designs and analyzes a job scheduling algorithm for virtualization platforms, and proposes a scheduling scheme based on the threshold dynamic scheduling model. In [19], in light of GA's flaws, an improved algorithm for optimizing scheduling is proposed, and GA with a double fitness function is considered to find nodes that reduce task scheduling's average and total times. The half-validity method, proposed in [20], is an improved method for maintaining the timing consistency of real-time data objects. The update period of real-time data objects is set to half the effective interval length of real-time data objects in this method. As a result, even in the worst-case scenario, this algorithm can guarantee the timing consistency of real-time data objects. To achieve better optimization of system resource use, it is also suggested in [21, 22] to delay the sampling time of update transactions as long as possible and use a dynamic periodic transaction deadline.

3. Method

3.1. Construction of CE Data Resources. Help students master various cognitive tools item by item and use them skillfully, so that they can successfully carry out autonomous learning and collaborative learning, according to the application requirements of various learning tools needed by universities to experience the information-based learning environment of English. Freshmen are given a week to experience the English autonomous learning system when they first start school. This model satisfies current national CE teaching reform requirements, particularly those related to teaching model reform; for example, "the reform of teaching model should cause English teaching to develop toward individualization, independent of time and place, and active learning."

The CE data resource database is designed to help people share resources and manage large amounts of data. Teaching resources refer to the most basic materials used in network teaching, such as graphics and images, audio and video, multimedia lesson plans, network courseware, and a test question bank. Because the platform is primarily used to implement streaming media resources, the development of resources is primarily focused on streaming media teaching resources. This platform can help teachers make better use of their teaching materials.

To begin, a large number of scattered network resources, teaching film, and television materials are collated by schools for many years, and school-based curriculum resources are collected and stored as video files with chapters as the unit, and each video file is divided into N segments according to the teaching needs, and corresponding text streams and HTML page indexes are inserted at each segmentation point to find or index the corresponding tex. The platform is divided into three parts: a streaming media producer, a server, and a client. A model diagram of an application platform is shown in Figure 1.

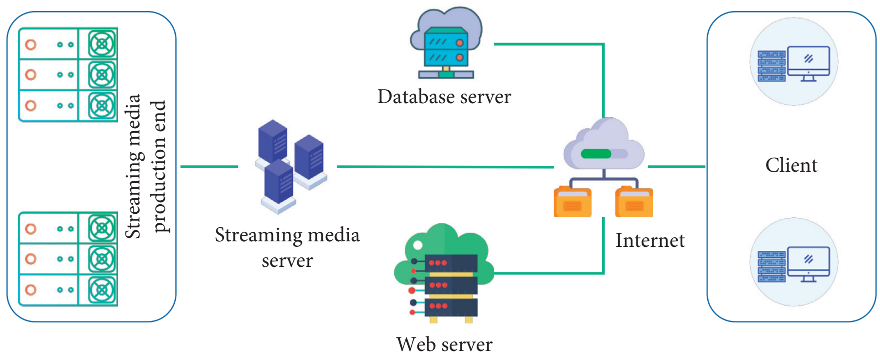

FIGURE 1: Model diagram of CE data resource pool.

The service interface subsystem provides external systems with interface services based on unified standards, such as the identity authentication interface and the resource metadata service interface. Metadata service interface includes metadata query, details browsing, behavior track, resource catalog, retrieval box docking, and other contents, which can meet the diversified resource application service needs of districts and schools. Figure 2 depicts the design of a specific functional structure.

The identity authentication interface and the metadata service class interface are both part of the service interface. Metadata service interface provides metadata query, details browsing, resource catalog, retrieval box docking, and other services. Identity authentication interface supports identity mutual trust among platforms based on joint authentication system. Metadata service interface provides metadata query, details browsing, resource catalog, retrieval box docking, and other services. A series of website security enhancements are being carried out in response to the characteristics of its Internet external service portal. The system patch is upgraded in time to strengthen the system security through vulnerability scanning and code auditing. Synchronous backup of the platform's core data is performed in the remote computer room to ensure that the remote computer room can carry web services if the main server room fails, and the digital resource sharing service platform's core services, such as web and exchange, can continue to operate.

Because each university offers a diverse range of disciplines and majors, the number of people who use it is naturally quite large, and each has its own set of needs, as well as different resources and materials. However, the web's educational resources system can meet such complex requirements, allowing for more open uploading, searching, and application of various teaching resources. With such a large resource pool, the system must meet specific storage capacity requirements, as well as stringent resource quality requirements. It is necessary to consider whether the resources are reliable and whether the system is in place.

Incorporate English teaching resources into the creation of digital English teaching materials, and gradually develop the school's own digital English teaching materials that are tailored to the needs of various grades, majors, and classes. Improve the usability of English textbooks and the rate at which they are used. From general English instruction to specialized English instruction, we have got you covered. As a result, incorporating high-quality teaching resources is critical. English teachers should integrate existing teaching resources with advanced teaching equipment, recognize the added value of teaching information, and adhere to strict teaching objectives. Teachers should have a thorough understanding of the meaning of digital technology, be able to use multimedia technology effectively in the classroom, and organically integrate the purpose and content of English instruction.

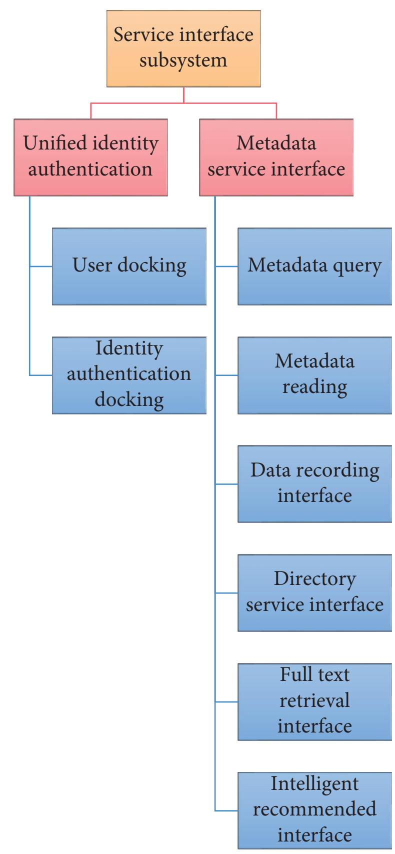

FIGURE 2: Service interface function structure.

3.2. Data Resource Optimization. Students are instructed, assisted, and encouraged to write "works" by their teachers. And the students are responsible for a large portion of the language input learning. Students learn in an autonomous learning center or over a local area network according to their own needs and levels, as determined by the teaching requirements and teachers' arrangements, embodying the principle of individualized instruction. Teachers can also recommend bibliographies and introduce network resources or Internet websites and assist students in developing the habit of self-study and increasing their self-assurance.

The units for task completion time, cost, and system load are all different. The fitness function is closely related to the comprehensive value of the weighted sum of these three indexes, so it is necessary to deal with the indexes so that there is no dimensional difference between them when designing the scheduling algorithm.

The actual value of the index and the evaluation value of the index are the two variables in a multiobjective comprehensive evaluation. There will be dimensional differences because each index has a different physical meaning. Resources in the cloud computing environment are dynamically heterogeneous, tasks are complex, and different types of tasks submitted by different users are also different. When designing GA, it is important to make assumptions about resource nodes and tasks and then base the algorithm's design on those assumptions, so that the algorithm can find a suitable allocation scheme for scheduling in a given environment.

Traditional network QoS (Quality of Service) usually refers to network speed, network reliability, and availability. QoS reflects consumers' satisfaction with the services provided. It is a comprehensive index. For example, QoS in the grid refers to the performance of a set of services, which determines the satisfaction of users with services. Research on QoS can be divided into three levels: application layer, system layer, and resource layer.

It expresses the objective function as the weighted sum of three-dimensional QoS objectives [23].

$$M(x) = \omega_1 * \text{time} + \omega_2 * \text{cost} + \omega_3 * \text{load}, \tag{1}$$

where $\omega_1 + \omega_2 + \omega_3 = 1$, $\omega_1, \omega_2, \omega_3$ refers to the weight coefficient of each index, *time* refers to the completion time, time refers to the cost, and load refers to the load.

Experimental tests show that the weight coefficient ratio of CPU (Central Processing Unit), memory, and bandwidth load is 4 : 3:15[48]. The penalty substitution iteration method is used to calculate the comprehensive load, and the specific formula is shown in formula (2).

$$\text{load} = 1 - \prod_{k=1}^{3} \left(1 - \text{load}_k\right)^{\omega_{Lk}}. \tag{2}$$

The overall goal of resource scheduling in this paper is to ensure system load while meeting users' QoS requirements, such as task time and cost. The three indicators are closely linked by comprehensive indicators. The smaller the values of these three indicators are, the more satisfactory the scheduling results can be for users, according to the problem analysis (Figure 3).

Suppose the population size is m, the fitness function value of individual i is f_i, and the probability of i being selected is flat P_i.

$$P_i = \frac{f_i}{\sum_{i=1}^{n} f}. \tag{3}$$

P_i represents the proportion of the fitness of individual i in the sum of all individual fitness in the population. The greater the fitness value of an individual, the greater the chance of being selected.

The execution time of the update transaction job is not fixed due to various factors that may affect the actual update of the transaction, but it often changes dynamically with the influence of the actual running environment of the system at the time, and this change is sometimes very significant and substantial. The purpose of this paper is to improve and supplement the shortcomings of the DS-FP (Deferring-Scheduling Fixed-Priority) method in the application of software/fixed real-time systems. The calculation time of updating transaction jobs obeys a certain probability density function distribution [24] after using the probability statistics method to design the system, ensuring that the results of job scheduling and transaction execution meet the system's performance requirements.

In DS-PS method, for $i < j$, suppose $T_i < T_j$, when any job $J_{i,j}$ of T_i is ready; the worst case is that all jobs with priority not lower than $J_{i,j}$ are also ready at the same time. If the sampling time $r_{i,j+1}$ of the next job $J_{i,j+1}$ of transaction job $J_{i,j}$ is delayed to $r_{i,j+1}$, then:

$$r'_{i,j+1} = d_{i,j+1} - R_{i,j+1}\left(r'_{i,j+1}, d_{i,j+1}\right), \tag{4}$$

where $R_{i,j+1}(r'_{i,j+1}, d_{i,j+1})$ is the response time of job $J_{i,j+1}$ in $[r'_{i,j+1}, d_{i,j+1})$. In this case, $J_{i,j+1}$ is allowed to have the following number of jobs ready at most in T_i within $[r'_{i,j+1}, d_{i,j+1})$ time period after sampling:

$$hp_i\left(d_{i,j+1} - r'_{i,j+1}\right) = \sum_{i'=1}^{i-1} \left\lceil \frac{d_{i,j+1} - r'_{i,j+1}}{P_{i'}} \right\rceil. \tag{5}$$

Within $[r'_{i,j+1}, d_{i,j+1})$ time, the execution time of all jobs with high priority $J_{i,j+1}$ in the system:

$$\Theta_i\left(r'_{i,j+1}, d_{i,j+1}\right) = \sum_{i'=1}^{m} \sum_{j=1}^{hp_{i'}(t)} C_{i',j}. \tag{6}$$

The formula (4) is as follows:

$$R_{i,j+1}\left(r'_{,j+1}, d_{i,j+1}\right) = \sum_{i'=1}^{m} \sum_{j=1}^{hp_{i'}(t)} C_{i',j} + C_{i,j+1}. \tag{7}$$

Therefore, DS-PS algorithm must obtain the delayed sampling time and absolute deadline of all high priority jobs before calculating $\Theta(r'_{i,j+1}, d_{i,j+1})$.

3.3. The Orientation Change of CE Teachers. The transformation and orientation of CE teachers' functions have become unavoidable, according to research on the

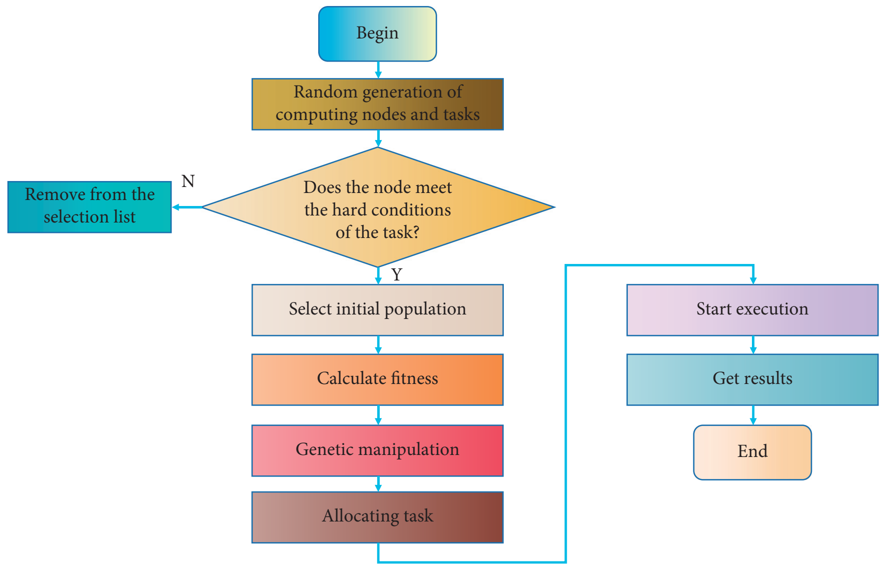

FIGURE 3: System diagram of resource evaluation model.

development status of CE teachers supported by digital technology.

Students actively collect and analyze relevant information and materials under the guidance of teachers, using multimedia and the Internet, and try to relate what they learn in the current learning content to what they already know. Effectively construct the meaning of the learned knowledge through the guidance of teachers and communication, discussion, and cooperation with learning partners, in order to improve our ability of information collection, information analysis, information processing, information innovation, and information expression, as well as cultivate our spirit of cooperation and innovation.

English teachers should use digital technology to create an active learning environment for their students. To achieve the best effect of English teaching, teachers should actively build a bond of trust in English teaching, release students' learning pressure, and eliminate their inferiority complex through two-way communication between teachers and students [7].

Teachers and students can use the Internet to ask and answer questions. This necessitates that teachers and students understand each other's teaching effect and that both sides work together to efficiently organize the teaching process in order to maximize the teaching effect. At the same time, students must understand their own learning effect after a period of study. The teacher's role at this time is also that of an evaluator, pointing out the students' accomplishments and advantages while also offering suggestions and guidance for their problems. Students will have a more accurate assessment of their learning situation if they are evaluated on time and in a reasonable manner. They will also be better prepared to learn in the future if they are evaluated on time and in a reasonable manner. The intrinsic motivation to motivate students to be positive is positive evaluation. Teachers should abandon traditional evaluation methods that primarily focused on test scores in favor of testing and evaluating students' learning performance and effect [9]. To ensure fairness and rationality in evaluation, teachers should conduct comprehensive evaluations on students, provide patient guidance and inspiration, and pay attention to the combination of personalized and process evaluations.

4. Results Analysis and Discussion

The more hands-on activities they participate in in the classroom, the better their hands-on ability, creativity, and sense of gain will improve. Teachers are proud of what they have accomplished. Under the information environment, there are two parts to the construction of CE digital teaching resources and teaching materials: English digital teaching resources construction and teaching materials construction.

In this experiment, the data involved are the attribute and number of cloud computing tasks, the attribute and number of resource nodes, the user's demand weight for time, cost, and load, the population size of GA, etc. Figure 4 shows the attribute values of 10 randomly generated tasks.

As an educator, even in the environment of students' autonomous learning, consider teaching issues from the perspective of pedagogy, and use nontechnical factors such as our emotions to urge students to learn better. At the same time, emphasize the psychological changes of students in the learning process, and solve their psychological problems in time. In addition, English teachers should strengthen their own research, be a researcher, keep up with the development of various ideological trends and new technologies, and apply the latest theories and technologies to teaching.

The results of simulation experiments show that the algorithm proposed in this paper is capable of selecting appropriate scheduling nodes for tasks based on users' needs and generating a satisfactory allocation scheme. The algorithm in [15] is compared to the algorithm in [19] in three ways: task completion time, cost, and the value of the

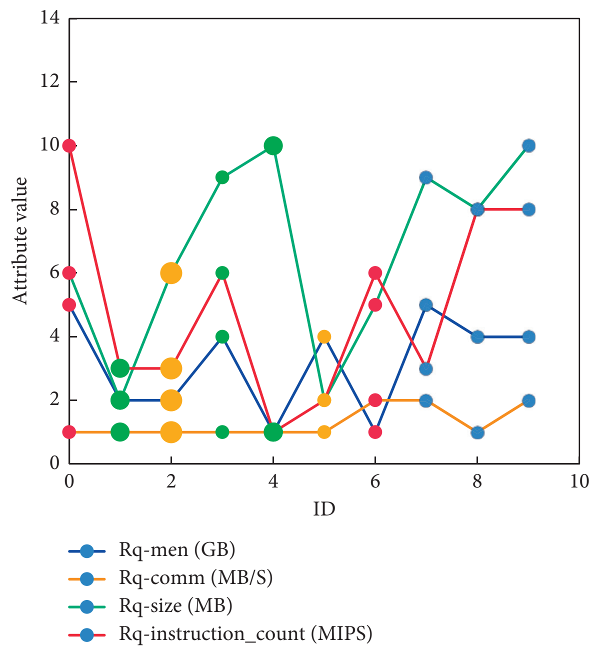

Figure 4: Task attribute value.

comprehensive objective function. The results shown in Figure 5 are the ones that were obtained.

Ninety percent of users of cloud computing want to get satisfactory service at the lowest possible cost. Analyzing from the constraint index of cost, the cost of the three algorithms will be higher and higher, but the cost of the algorithm in this paper is less than that of the algorithms in [15, 19].

In classroom teaching, teachers communicate with students mainly by asking questions. The learning process adopts the static teaching method, and students' learning thinking is limited, so they cannot learn independently, and it is difficult to communicate and exchange with English knowledge.

English teachers must improve their classroom knowledge, teaching activity design, student psychology, and teaching resource development, among other things. The teacher's role is similar to that of a traditional teacher in this regard. Teachers should plan and organize an entire stage of the teaching process, not just a single class, that is, in a macrosense, the organizer. This demonstrates that teachers should plan and organize the selection of students' learning materials, the formulation of students' learning objectives, the organization of the learning process, and the evaluation of learning effect based on the students' current situation. Figure 6 shows that as the number of tasks grows, the time required by the three scheduling algorithms grows. However, the algorithm in [19] takes less time to complete in total than the algorithm in this paper.

The objective function values of the two algorithms are very similar when the number of tasks is less than 40, but when the number of tasks exceeds 40, the objective function values obtained by the algorithm proposed in this paper are less than those obtained by the algorithms in [15] and [19]. As a result shown in Figure 7, in terms of overall performance, this algorithm outperforms the other two algorithms.

The system's load is an important consideration when allocating resources. Users can make the algorithm choose the best computing node for the task based on their own load weight coefficient setting through simulation experiments. The worth of a load will rise as well. Because the weight coefficients are set differently, the load values of the three algorithms will differ. The load calculation of the algorithm in [15], on the other hand, is based on a formula that ignores the needs of users. As a result, from a broad perspective, this algorithm can better meet various QoS requirements.

As shown in Figure 8, the real-time data object can guarantee the timing consistency requirement in this update transaction scheduling process, ensuring the system's overall performance. The first two methods can also guarantee 100 percent of the service quality requested by users and even improve the execution service quality above the service quality requested by users. When deterministic scheduling methods, such as those in [21] and [23], are applied in the software/fixed real-time system, it is shown that our previous strategy of reducing the schedulability of the system to ensure the correctness of the system performance is really harsh or pessimistic.

The network's all-around communication between teachers and students, as well as students and students, has reduced the psychological distance between them and increased the opportunities and scope of communication between them. Teachers can better understand the doubts, difficulties, and main problems that students face in learning by using statistical analysis of the types, times, and numbers of students' questions, which provides a realistic and effective way for personalized teaching. The CPU resource

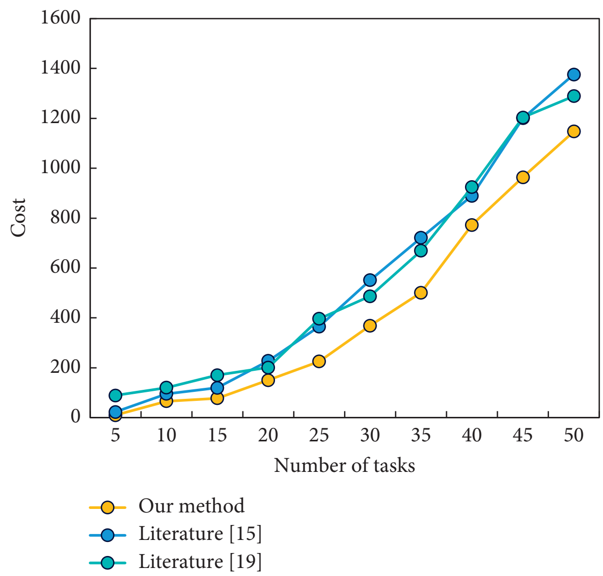

Figure 5: Cost comparison chart.

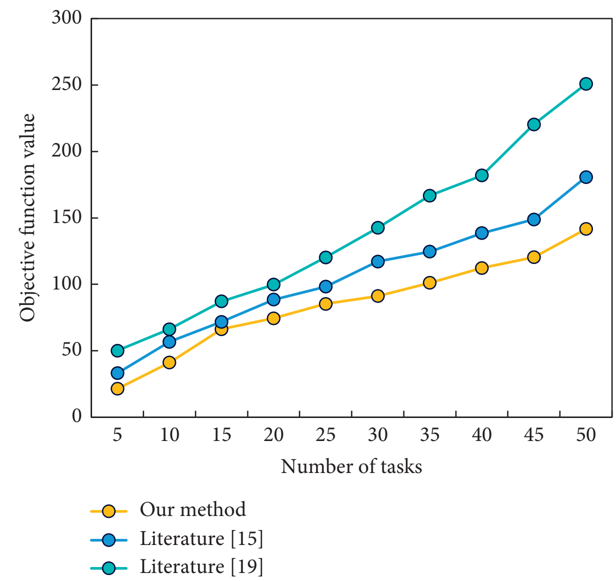

Figure 7: Comparison chart of objective function values.

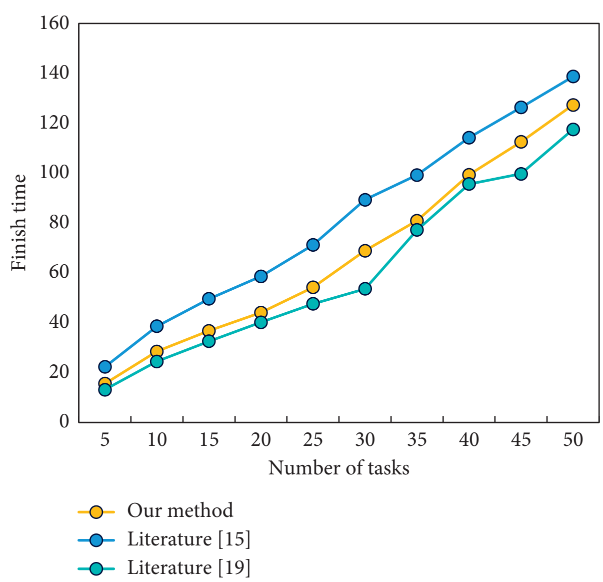

Figure 6: Comparison chart of completion time.

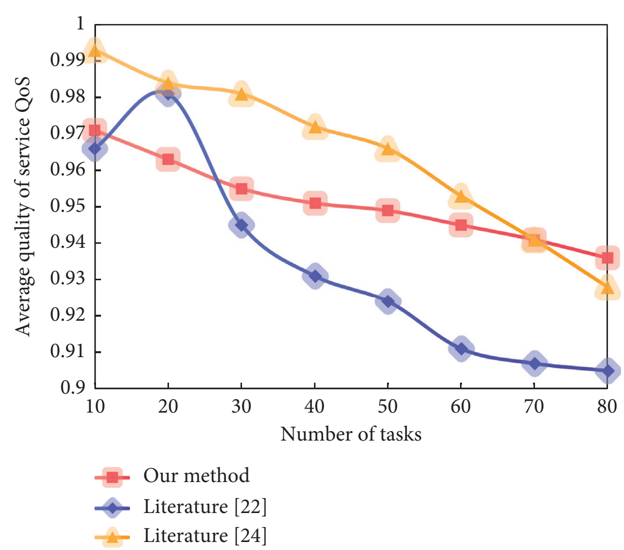

Figure 8: Comparison of the relationship between the average QoS of arrival of three methods and the number of transactions executed.

utilization rate of the three methods increases monotonically with the number of scheduled update transactions, as shown in Figure 9.

The main goal of DS-PS method is verified and realized (that is, while trying to delay the cycle of transaction operation, the calculation time of the operation is less than that in the worst case, thus reducing the utilization rate of CPU resources in the system).

Students-centered, teaching-centered programs improve students' overall performance, help them adapt to job demands, and help them better serve society, improving unified planning and design in the resource database building process, as well as integrating the resource application level. Teachers can use the platform of teaching resource pool to select the best teaching resources, design the most effective teaching process, achieve the best classroom teaching effect, meet the needs of students, and complete the teaching objectives.

The CPU resource utilization ratio of the method in [21] and the method in [23] when executing the scheduling update transaction under the condition that the QoS requested by users is different remains equal, as shown in Figure 10, because the system will still strictly require that the update transaction be executed to provide the service quality guarantee, even if the service quality requested by users is processed by these two methods.

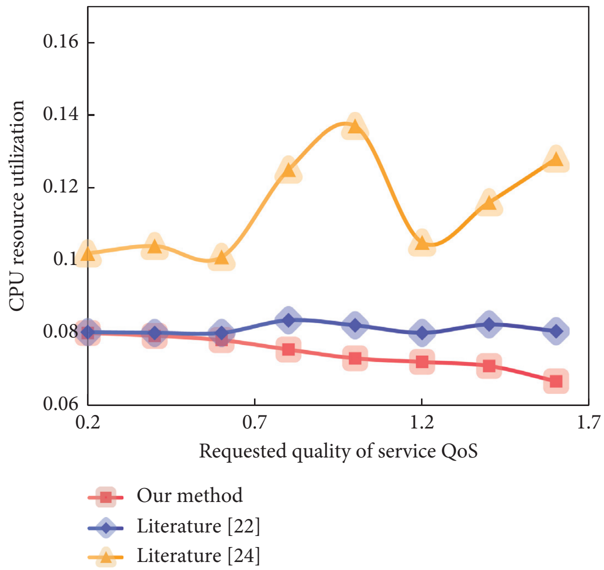

FIGURE 9: Comparison of the relationship between the number of transactions scheduled by three methods and the utilization rate of CPU resources.

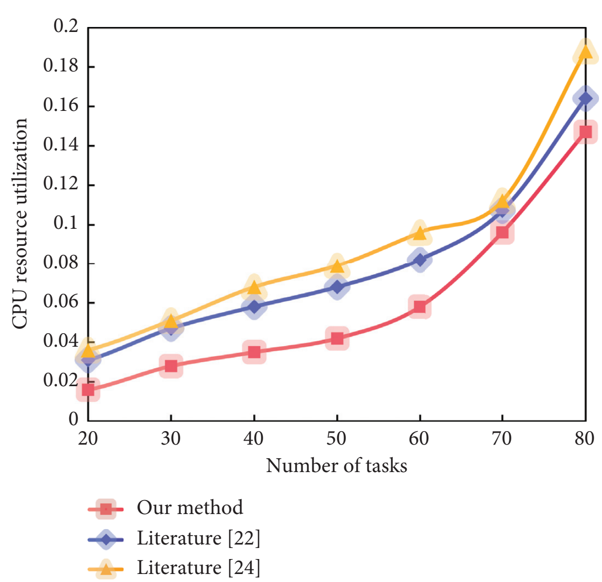

FIGURE 10: Comparison of three methods in relation between requested QoS and CPU resource utilization.

This also demonstrates that the DS-PS method can lower the quality of service of requests in exchange for increased system schedulability, making the DS-PS method more flexible in scheduling transaction job update operations and thus improving system performance.

Update resource management in the resource library on a regular basis, and improve resource construction management and application. Schools should use corresponding incentive mechanisms to ensure the long-term and dynamic construction process of resource pools in order to study the long-term mechanism of resource standardization and resource pool construction, acting as planners, organizers, guides, facilitators, designers, managers, supervisors, monitors, collaborators, and evaluators in the classroom to mediate students' learning process from teaching content, teaching methods, task setting and implementation, and other factors. This necessitates that teachers possess certain qualities, including knowledge of pedagogy, psychology, and other related topics, as well as the ability to use modern information technology, such as multimedia and network technology.

5. Conclusion

This research presents a relatively comprehensive construction scheme for a CE data resource base based on a web database, which allows users to upload, edit, download, read, and use teaching multimedia resources. GA is designed to solve the resource scheduling problem, and the objective function is obtained by integrating the three indexes of task completion time, cost, and load balance. The process of algorithm execution, preconditions, and assumptions, the unique environment of cloud computing, and the strategy selection of three types of genetic operations are all examined in this paper. In a cloud computing environment, a resource scheduling optimization strategy based on QoS constraints and GA is proposed. CE data resource pool can further integrate CE high-quality resources to achieve balanced supply, which has significant social benefits and plays an important role in expanding the coverage of CE high-quality education resources, promoting education equity, and improving the quality of school education and teaching.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author does not have any possible conflicts of interest.

Acknowledgments

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Retraction

Retracted: Construction of the Cross-Cultural Interaction Model for International Students Based on Big Data Analysis

Scientific Programming

Received 29 August 2023; Accepted 29 August 2023; Published 30 August 2023

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] Z. Wang and S. Gao, "Construction of the Cross-Cultural Interaction Model for International Students Based on Big Data Analysis," *Scientific Programming*, vol. 2022, Article ID 3133872, 9 pages, 2022.

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Volume 2022, Article ID 3133872, 9 pages
https://doi.org/10.1155/2022/3133872

Research Article

Construction of the Cross-Cultural Interaction Model for International Students Based on Big Data Analysis

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Culture is an important feature that distinguishes human beings from animals. Human beings have created and developed various cultures and influenced people's psychology and behavior in different social forms. With the continuous improvement of China's international influence and cultural soft power, the number of foreign students studying in China is increasing year by year. In this paper, data mining is carried out on the data of international students, and the cross-cultural interaction model of international students is constructed. According to the characteristics of the research object, this paper explores the influence of cultural novelty and psychological capital on its cross-cultural adaptation in order to provide theoretical basis for the improvement of cross-cultural adaptation. It also promotes the better development of international students and the improvement of international exchange management in colleges and universities by providing some ideas for mental health education and management of international students. The importance of cultural study for international students in China is related not only to the development and improvement of foreign students' cognitive level of target culture, but also to the external communication of national cultural image.

1. Introduction

The trend of economic globalization not only brings closer economic and political exchanges between countries, but also brings more frequent educational exchanges and more developed educational services trade, resulting in the international study abroad fever [1]. International students will form their own understanding and cognition of Chinese image and culture while studying and living in China, and they will also bring their defined Chinese image back to their home country once their studies are completed [2]. International students in China can learn about foreign cultures and broaden their horizons by studying abroad, but coming from their home country to the host country also means dealing with cultural differences [3, 4]. In order to provide a comfortable learning and living environment for international students studying in China, the Ministry of Education and universities are constantly improving relevant procedures, education management systems, and professional training plans for international students studying in China, as well as allocating a large amount of funds to improve the hardware construction level of universities [5]. In this new era, data is no longer simply piled up and stored, and the ability to filter and utilize data is the criterion to judge whether a system can handle and load big data.

As messengers of cultural exchanges, international students lay human capital and cultural capital for bilateral coordinated development and further deepen international cooperation [6]. At present, there are millions of students studying abroad all over the world, and the number of international students has reached an unprecedented scale and leap-forward development. The process of cultural adaptation is also a complex process of resocialization or "secondary growth" [7]. The final academic and study quality of overseas students depends on the effectiveness of solving the adaptation problems in language, environment, eating habits, studies, and so on, and the effective adaptability has a great influence [8]. If the foreign students cannot effectively face the cultural impact of the host country, maladjustment will also damage their mental health, which to some extent means the failure of foreign students' families and national education investment [9]. The effect of foreign students' cultural learning not only is related to their cross-cultural life experience, but also affects the external communication effect of Chinese culture to a great extent [10]. Therefore, paying attention to the significance of foreign students' cultural study in China is not only conducive to the development and improvement of foreign students' cognitive level of target culture, but also related to the external communication of national cultural image. According to the characteristics of the research object, this paper explores the influence of cultural novelty and psychological capital on its cross-cultural adaptation and carries out data mining on the data of international students to build a cross-cultural interaction model for international students.

With the rapid development of international education in China, the country has risen to become the world's third largest destination country and Asia's largest. As a result, academic circles are paying more attention to research on international students in China [11]. International students' cross-cultural adaptation has become a source of concern. As a result, education administrators should prioritize learning how to effectively educate and manage international students, as well as improving their cross-cultural interaction [12]. Positive self-efficacy, a positive outlook on life, and tenacious willpower are all important factors in international students' cross-cultural adaptation activities in China [13]. As a result, educational institutions must provide timely, scientific, and comprehensive cultural adaptation counseling to international students in China, in order to improve the continuous release of collective internal pressure by international students in China and then to strengthen their individual psychological resilience. The degree of difference between the culture of the home country and the culture of the country of residence recognized by people living in other countries is referred to as cultural novelty [14]. Because of individual differences, everyone has different cultural understanding of the home country and the target country. Understanding cultural distance with cultural novelty can better reflect cultural differences from the individual level. In this study, a mixed research method combining qualitative and quantitative methods was adopted, and the research steps were planned according to the exploratory sequence design scheme. This paper probes into the influence of cultural novelty and psychological capital on their cross-cultural adaptation. Data mining is carried out on the data of international students, and the cross-cultural interaction model of international students is constructed. This paper analyzes the influence of gender, time in China, Chinese proficiency, and country on the use of cultural learning strategies by foreign students.

2. Related Work

The cross-cultural adaptation of international students in China is a material derived from the integration of individual international students and the external ecological environment, according to [15], which is based on the cross-cultural adaptation model from the perspective of psychological capital. From the perspective of psychological capital, [16] discusses the management of a cross-cultural adaptation model for Chinese students. Reference [17] examines cultural learning strategies that have not been thoroughly explored in the field of second language learning strategies from the perspective of cross-cultural communication. Reference [18] develops a survey tool to analyze the current situation of cultural learning strategies used by international students in China, as well as a classification system for cultural learning strategies for international students in China. In addition, it investigates the factors that influence cultural learning strategies. Reference [19] discusses and analyzes the factors influencing cross-cultural adaptation from the perspective of cross-cultural adaptation, using interview and questionnaire research methods. Reference [20] points out that individuals and groups in cross-cultural contact will adopt strategies for acculturation, and two important issues related to strategies are the preservation of the original culture or the contact and participation of the new culture. Reference [21] holds that the definition of "culture" is the conceptual basis for constructing the theoretical framework of cultural learning research. Without a reasonable definition and explanation of culture, it is difficult to scientifically define and substantively discuss the connotation, content, and purpose of cultural learning. Reference [22] points out that individuals and groups in cross-cultural contact will adopt strategies for acculturation, and two important issues related to strategies are the preservation of the original culture or the contact and participation of the new culture. In this paper, data mining [23] is carried out on the data of international students, and the cross-cultural interaction model of international students is constructed, thereby providing theoretical support for cross-cultural adaptation research, especially providing theoretical analysis and explanation for cross-cultural adaptation of international students with different cultural distances.

3. Analysis of Influencing Factors of Cross-Cultural Adaptation

Culture is an important feature that distinguishes people from animals. Human beings have created culture, which in turn influences individual psychology and behavior. When people move from one cultural situation to another, they show psychological uneasiness and behavioral discomfort due to the constraints of the original cultural elements, but culture is learnable and dynamic, and people also have initiative. Therefore, when people enter the second cultural situation, they will make adjustments to changes, that is, cross-cultural adaptation, which is embodied in psychological adjustment and the acquisition and application of the second cultural elements.

With the advent of the era of economic globalization, it has not only greatly promoted the development of Chinese economy and culture, but also brought the upsurge of studying abroad. As a bridge of cultural exchange, international students studying in China lay a good human foundation for the coordinated development between countries. It is the program written by culture and placed in people's mind in advance. These programs are the entirety of people's life style in a broad sense in a specific society. They are the one-benefit and collective spirit programs, which determine individual emotions [24], behaviors, and cognition [25]. However, different from computers, human beings as individuals are an open and active system. On the one hand, their behaviors are partially controlled by mental programs, but on the other hand, people may deviate from or modify this program by exerting their individual initiative, showing new ways of emotion, behavior, and cognition. With the increasing number of Chinese students studying in China, to some extent, it has effectively promoted the two-way development of national economy and traditional culture. However, there are still some adverse effects; that is, a large number of international students studying in China have a series of potential unstable factors, the most well-known performance of which is the problem of cultural adaptation.

The psychological adjustment that people make to their social environment is known as adaptation. Every stage of a person's life, including childhood, adolescence, middle age, old age, and death, involves psychological adjustment and change, which is the process of adjusting to one's social environment. Self-acceptance, self-enrichment, satisfaction, happiness, and other outcomes of adaptation can be seen. On the contrary, even physical and mental organizations are harmed and dysfunctional. The cultural distance between the two countries is an objective measure of their cultural similarities. Some people believe that psychological distance is caused by spatial geographical distance or cultural circle. Cross-cultural anxiety is almost a necessary stage for every international student, but it is difficult to manage and can even cause physical discomfort. For cross-cultural adaptation, cultivating international students' positive attitude toward life and optimistic quality is critical [26]. In practice, group counseling can be used to teach international students to form positive attribution styles, to use their own advantages to increase self-awareness, to enable international students to gain positive energy, and to use these forces to adapt to cross-cultural life, according to the explanatory style theory, expectation theory, and learned optimism theory.

Individuals can acquire and use their inner strength to improve themselves in a short time and overcome the obstacles of cross-cultural adaptation. Its flexibility, benefits, and investment characteristics make psychological capital become a more attractive way to adjust the level of cross-cultural adaptation. The influencing factors of cross-cultural adaptation are shown in Figure 1.

From the perspective of culture, cross-culture can be understood as cultural identity; that is, the attribution and acceptance of a particular culture by cross-cultural groups or individuals is a culture that crosses the boundaries of different countries and nationalities and has its specific value orientation. Cross-cultural adaptation is a complicated process. At present, there are many cross-cultural interaction models put forward by academic circles, and the research focuses on many explicit influencing factors. However, most models seem to regard cultural adaptation as passive behavior and develop many more negative concepts. We know from the investigation and research that international students have a high rate of mental illness at this time. International students' cross-cultural misadjustment not only has a negative impact on their personal development, but also has a negative impact on the overall social development and causes some intercountry contradictions. Cross-culture is a social phenomenon that emerges in the course of human history's continuous evolution and is unavoidable. The rise in social mobility and the cohabitation of different ethnic groups are the primary causes of this phenomenon. The cross-cultural phenomenon will become increasingly obvious as the globalization era progresses. In the collision and integration of different cultures, the essence of this phenomenon is to change traditional and existing cultures and to create new cultures.

4. Cross-Cultural Interaction Model of International Students Based on Big Data Analysis

At present, self-awareness and ability of international students in China are the main factors that affect cross-cultural adaptation. It mainly includes the self-learning experience, personal experience, physical function of foreign students in China, and the self-coping ability of the external living environment changes. The cross-cultural interaction model based on big data is a descriptive model, which is based on the understanding of the changing characteristics of cross-cultural adaptation and psychological capital. The three adaptations explore the emotional, behavioral, and academic state of international students from different analytical frameworks, as shown in Figure 2.

People's adaptation implies that people may change the social environment. It is possible for people to change the social environment, but it is more likely for people to change when they only have group strength. The energy for the state can be defined as

$$\begin{aligned}\Delta w_{jk} &= \eta \delta_k^o y_j = \eta\left(d_k - o_k\right)\left(1 - o_k\right) o_k y_j,\\ \Delta v_{ij} &= \eta \delta_j^y x_i = \left(\sum_{k=1}^{l} \delta_k^o w_{jk}\right)\left(1 - y_j\right) y_j x_i.\end{aligned} \tag{1}$$

Deep mining data, using radial basis function:

$$\begin{aligned}p(x, y) &= \frac{\sum x_1 y_1 - n\overline{xy}}{(n-1) s_x s y}\\ &= \frac{n\sum x_1 y_1 - \sum x_1 \sum y_1}{\sqrt{n\sum {x_1}^2 - \left(\sum x_1\right)^2}\sqrt{n\sum {y_1}^2 - \left(\sum y_1\right)^2}}.\end{aligned} \tag{2}$$

By polynomial kernel function:

$$T(x, y) = \frac{x \bullet y}{\|x\|^2 \times \|y\|^2} = \frac{\sum x_1 y_1}{\sqrt{\sum {x_1}^2}\sqrt{\sum {y_1}^2}}. \tag{3}$$

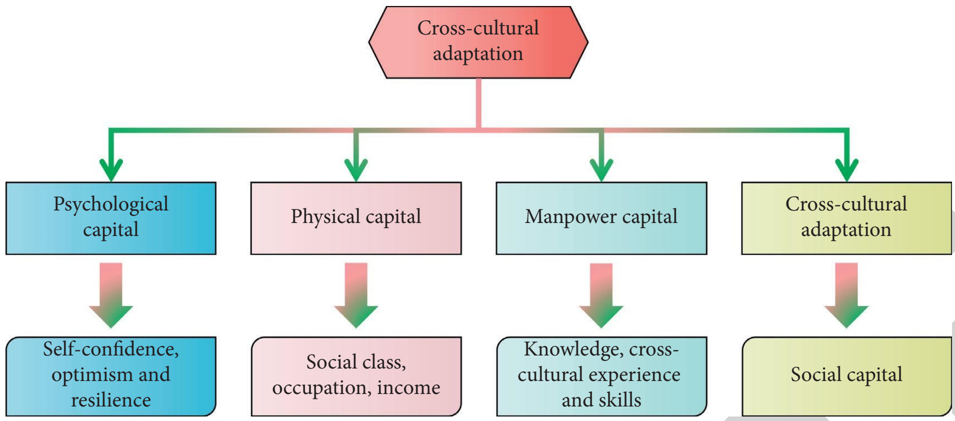

Figure 1: Influencing factors of cross-cultural adaptation.

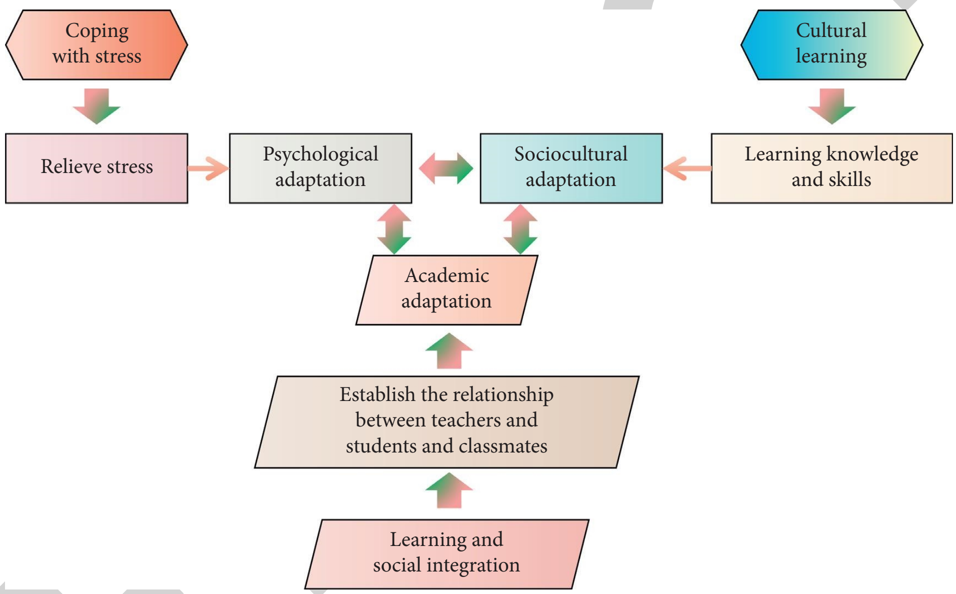

Figure 2: Structural model of students' cross-cultural adaptation.

When the parameters are fixed, it is simplified as follows:

$$d(x, y) = \sqrt{\left(\sum (x_1 - y_1)^2\right)}. \tag{4}$$

Positive psychological adaptation, from a cognitive standpoint, entails forming an objective and rational view of oneself and the host country group, as well as implementing integration strategies in cultural situation transformation. However, due to international students' limited residence time and the constraints of academic tasks, it is difficult to form an objective and rational viewpoint in a short period of time. For international students' cross-cultural adaptation, positive self-efficacy, an upbeat attitude, a sense of hope, and perseverance are essential factors. Conscious psychological capital exercises can help people better understand stress and increase their psychological resilience to it. The cross-cultural interaction model based on big data and psychological capital is shown in Figure 3.

The cognitive process is influenced not only by individual factors affecting international students, but also by the host society's overall attitude toward foreigners, i.e., openness and acceptance of foreigners. International students with a strong sense of hope will set attainable goals, plan specific and attainable paths to achieve those goals, dare to overcome obstacles, and carry out the plan, and it will be difficult to give up halfway due to external influences. As a result, a group intervention program tailored to international students can be designed to improve their hope quality and assist them in experiencing happiness while participating in cultural exchange. Because most international students in China are nondegree students with a short stay in China (more than half of the time spent in China by Wood Research Institute is less than a year), cognitive factors are not considered in the psychological adaptation results. It is critical for cross-cultural adaptation to cultivate international students' positive outlook on life and optimistic quality.

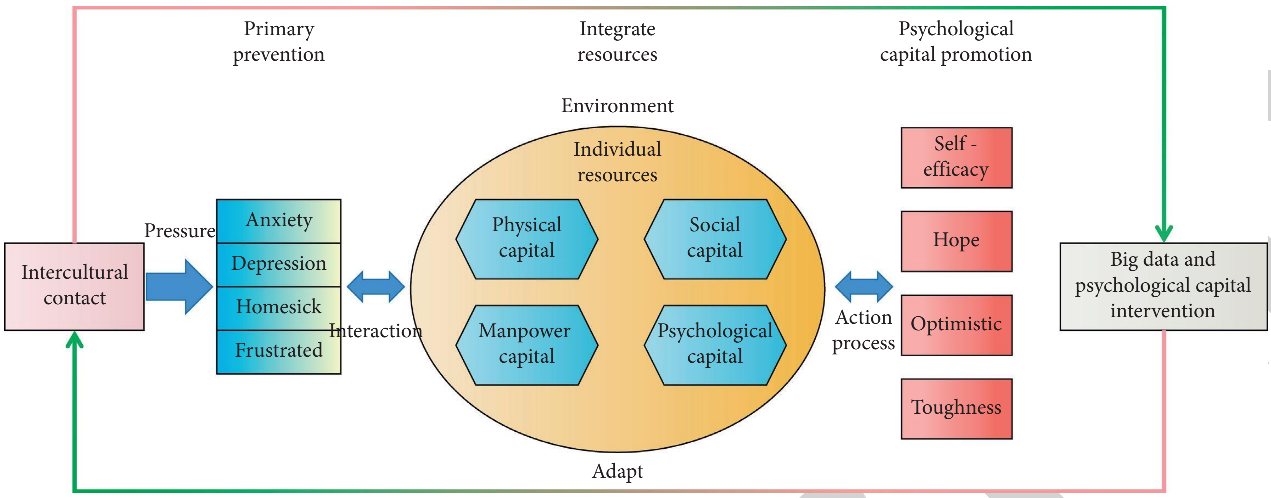

Figure 3: Cross-cultural interaction model.

Data preprocessing is a part of data mining in a broad sense. The data preprocessing work in this project is as follows. There are two relationships between the previous database fields: functional relationship and correlation relationship. An arbitrary n-dimensional to m-dimensional mapping can be accomplished with a three-layer neural network. The number of neurons in the hidden layer is $s = \sqrt{n + m} + a$, and n and m are the number of nodes in the input and output layers, respectively. The activation function of the neurons in the hidden layer is selected as the hyperbolic tangent function, and the function form is

$$f(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}. \tag{5}$$

The activation function of the output layer uses Sigmoid excitation function, which is in the form of

$$f(x) = \frac{1}{1 + e^{-x}}. \tag{6}$$

The induced local domain of a neuron J in the hidden layer is

$$v_j(p) = \sum_{i=1}^{n} w_{ij} x_i - \theta_j. \tag{7}$$

The induced local domain of a neuron K in the output layer is

$$v_k(p) = \sum_{j=1}^{s} w_{jk} v_j(p) - \theta_k, \tag{8}$$

where n and s are the number of neurons in the input layer and the hidden layer, respectively.

In practice, group counseling can be used to teach international students to form positive attribution styles, to use their own advantages to increase self-awareness, to enable international students to gain positive energy, and to use these forces to adapt to cross-cultural life, according to the explanatory style theory, expectation theory, and learned optimism theory. The self-identification of international students with Chinese traditional culture and their understanding of international cultural differences severely impedes their own development. In the process of self-cross-cultural adaptation, the material capital and social capital in the self-capital of foreign students in China have become an indispensable part of their self-growth. The mobilization of resilience mechanisms in the adaptation process will, to some extent, encourage international students in China to solve problems in the process of adaptation in a scientific and reasonable manner.

5. Result Analysis and Discussion

At present, a large number of experimental data prove that self-efficacy is closely related to external life situations. It is inevitable that foreign students in China will encounter some problems when they first come to China. At this time, the self-efficacy of foreign students in China begins to play a role. There are significant differences in the dimensions of daily life adaptation in three variables: gender, cross-cultural experience, and religious belief. It is more difficult for men who have cross-cultural adaptation and religious beliefs to adapt to daily culture, which shows that daily life adaptation is the most basic content for foreign students to contact with different cultures. Maybe men are less careful about trivial matters of daily life than women, and they are more likely to find it difficult to adapt to daily life. Cross-cultural experience also makes it easy for international students to constantly compare the differences of various cultures in the past, but it is even more difficult for them to let go to adapt to the new environment.

Specific intervention strategies to improve foreign students' self-efficacy include the following: during the actual enrollment process, the school should organize activities to help students better adapt to cross-cultural situations, so that foreign students in the class can continuously improve their self-efficacy while participating in activities, and provide them with a superior learning environment on campus. It is necessary to design role exchange activities between international students and Chinese students in the actual teaching activities, as well as to continue to increase the analysis of actual cases. We can effectively help international students fully experience the fun of learning by constantly stimulating their positive emotions and then comprehensively improving their actual survival and learning ability.

Hope is a positive psychological mechanism and a new field of positive psychology research that involves an individual's desire to achieve a specific goal. Hope influences not only an individual's life satisfaction, but also his or her coping style and ability to effectively overcome obstacles. In this way, hope affects an individual's difficult coping in a new cultural environment. Hope influences not only the degree of self-satisfaction of international students, but also their ability to overcome external challenges to some extent. We need to make mandatory intervention for foreign students who are having difficulties in China right away in order to effectively improve their self-efficacy and actual survival ability. International students with a strong sense of hope will set achievable goals, plan specific and feasible paths to achieve those goals, dare to overcome obstacles, and carry out the plan, and it is difficult to give up halfway due to external influences. Using this model to analyze various data of international students, we get the change curve of cultural novelty and social and cultural adaptation as shown in Figure 4. The curve of cultural novelty and depression is shown in Figure 5. The curve of psychological capital and social and cultural adaptation changes is shown in Figure 6.

As can be seen from the above figures, there is a significant positive correlation between cultural novelty and social and cultural adaptation. There is no significant correlation between cultural novelty and depression. Psychological capital is negatively correlated with social and cultural adaptation. The data analysis methods used in this study are mainly divided into qualitative data and quantitative data analysis methods. As far as the analytical perspective of qualitative research is concerned, on the one hand, this study emphasizes the interpretation perspective of data center and tries to abandon the unverified speculation held by itself, so as to prevent subjective and one-sided interpretation of interview materials. However, on the other hand, in order to ensure the breadth and depth of qualitative data analysis, it is necessary for researchers to obtain corresponding theoretical guidance on the methodology of data interpretation, which can not only make an overall description of the use of foreign students' cultural learning strategies, but also make a partial close-up of the influence and effectiveness of specific strategies. For the analysis of quantitative data, this study uses statistical software for processing. From the results of the study, we can see that cultural novelty sometimes has a positive relationship with cross-cultural adaptation, while sometimes it has a negative relationship. It shows that there is a variable that affects the direction and strength of the relationship between cultural novelty and cross-cultural adaptation. As far as this study is concerned, psychological capital can be considered as the moderating variable.

Education must provide multilevel learning tasks for international students, ranging from simple to complex, so

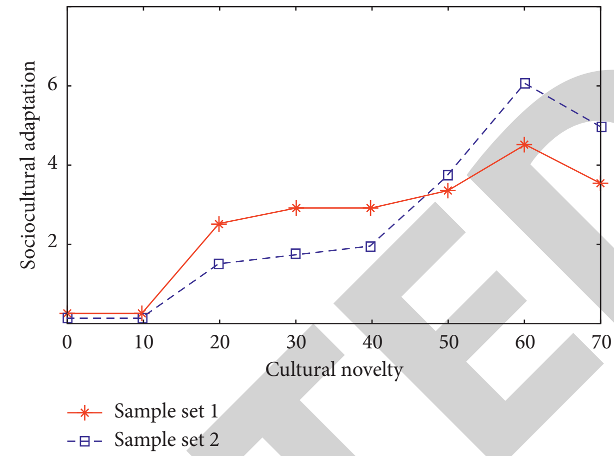

FIGURE 4: Changes of cultural novelty and social and cultural adaptation.

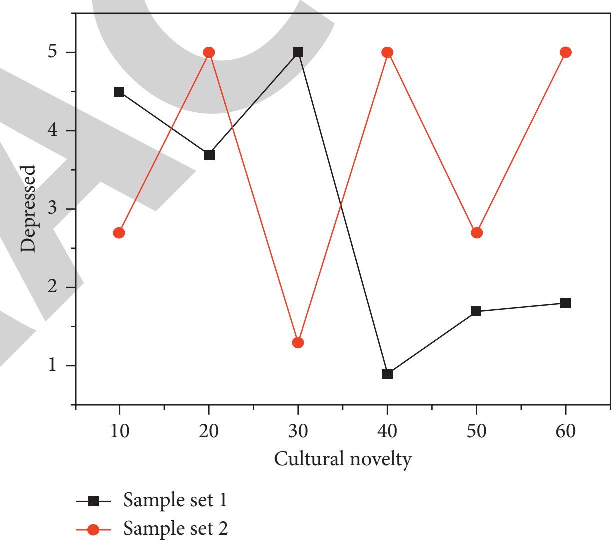

FIGURE 5: Cultural novelty and the result of depression change.

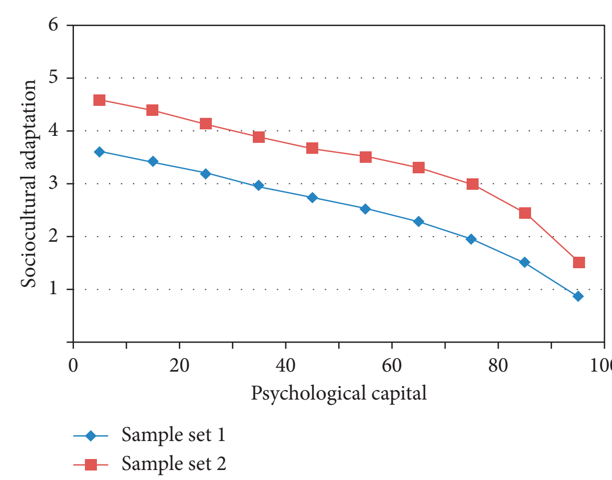

FIGURE 6: Psychological capital and social culture adapt to the changing results.

that students can continuously improve their ability to solve problems in a stable state, thereby fully stimulating international students' motivation and continuously improving related cultural adaptation functions. Individuals' sense of hope can be improved more effectively through group intervention, according to studies. As a result, a group intervention program tailored to international students can be developed to improve their hope quality and assist them in experiencing happiness through cultural exchange. It can specifically assist international students in setting short-term goals with small steps while also stimulating their path thinking and dynamic thinking, that is, increasing their cognitive belief in their ability to find the target path and increasing their motivation to move forward along the target path. This model is compared to an existing model to ensure that it performs as expected, as shown in Figure 7.

It can be seen that this method is faster than the existing methods in operation time and is superior to the existing methods on the whole. The method used in this paper is the principal component analysis of data. However, the first problem encountered in the process of data principal component analysis is how to analyze unknown types of data. Here, we use several numbers as dummy variables of the form. If there are only two categories of target data, such as gender data, we can simply set one category as 1 and the other categories as 0. However, some data items contain two or more variables. Therefore, using multiple dummy variables to analyze data is a solution, so it is necessary to build more variables with numbers to represent multiple data types. People with high self-efficacy handle things rationally and dare to accept challenges. Comparing this algorithm with other algorithms, the calculation error is shown in Figure 8.

It can be seen from Figure 8 that the other two algorithms have higher errors. On the whole, compared with the other two algorithms, this algorithm has smaller error and higher accuracy. The superiority of this method is further proved. The cultural distance perceived by graduate students is smaller, and the cultural distance perceived by foreign students with more friends is smaller. And the variables of age and length of stay in China are further found in back testing. The scores of cultural novelty of international students aged 18 are significantly higher than those of international students under 18; that is, they perceive that there is a small gap between the culture of the host country and that of the home country. It shows that, due to the increase of experience, the perception of cultural differences may be low. However, the international students who have been in China for the longest time have the smallest perceived cultural distance, reaching a statistically significant level. It can be seen that time is a factor that affects the cultural novelty of international students. With the familiarity with the environment, the strangeness of foreign students will gradually disappear. Exploratory factor analysis of the data, as a validity test, can also determine whether the strategy dimension divided by qualitative research can be supported in the data, and orthogonal rotation is carried out by principal component analysis and maximum variance rotation method.

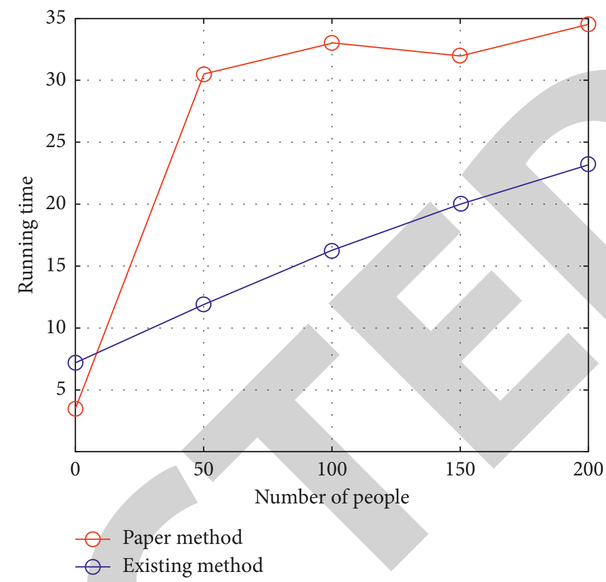

Figure 7: Comparison results of running time of two methods.

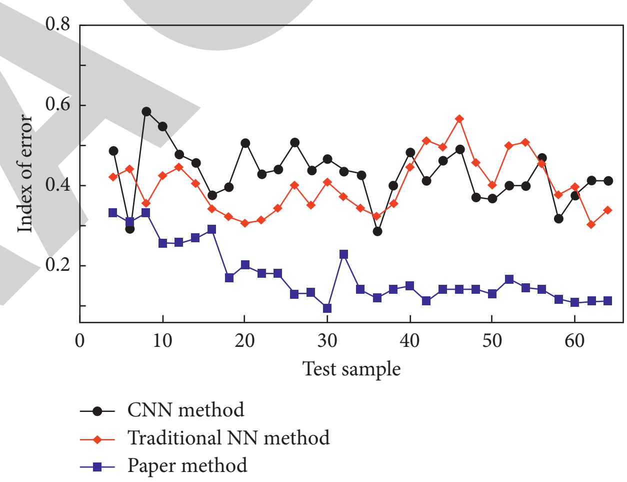

Figure 8: Comparison results of calculation errors of different methods.

A five-factor social and cultural adaptation scale can be obtained after exploratory factor analysis and confirmatory factor analysis. Cultural value adaptation, day-to-day life adaptation, pressure and risk adaptation, social interaction adaptation, and language skills are some of them. The validity and reliability of the data are both satisfactory. This paper uses a mixed research method to look at international students' cultural learning strategies in qualitative data and statistically explain how they are used in quantitative data. The mixed research method can not only broaden the types of data sources and increase the number of participants, but also investigate how foreign students in China use cultural strategies through various research paths, enhancing the credibility of the research findings.

6. Conclusions

This paper investigates the cross-cultural adaptation of international students in China at the individual level through a literature review, questionnaire survey, and statistical analysis that combines descriptive and inferential statistics. The main findings of the cross-cultural adaptation research of international students in China will be summarized on this basis, and effective strategies for optimizing international student management in colleges and universities will be discussed based on the findings and theories of this research. This paper investigates the impact of cultural novelty and psychological capital on cross-cultural adaptation and conducts data mining on international student data to develop a cross-cultural interaction model for international students, based on the characteristics of the research object. The state should refine the entrance examination standards for international students in China, improve the preparatory education system for international students in China, and improve the training mode for international students' education and management professionals, among other suggestions and countermeasures for cross-cultural adaptation guidance for international students in China. Colleges and universities in China should improve humanistic care and mental health education for international students, as well as innovate international student education and management methods. International students should focus on improving their personal willpower, continually strengthening their knowledge reserves and social practice abilities, gradually expanding their personal social circle, actively accepting Chinese culture, and striving to improve their Chinese learning and application ability.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

Research on the Combination Technology of Cultural and Creative Industries Based on TRIZ Theory

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In recent years, the cultural and creative industry has become an emerging industry that countries have vigorously supported and promoted in the new economic era. This article introduces the TRIZ innovation theory into the cultural and creative industry. As an innovative problem-solving theory, TRIZ has good practicability and operability. It seeks breakthroughs on the basis of original creative thinking and provides a scientific and efficient cultural creativity. Combining specific cases, analyze the innovative principles of TRIZ theory as the origin, stimulate creative methods that generate divergent thinking, aggregate thinking, and conversion thinking, and apply them to creative mechanisms and applications in cultural advertising creativity. The whole process is guided by rational principles to lead perceptual thinking, and concrete principles drive abstract imagination, exploring the source of thinking of the essence of cultural advertising creative design. This theory and its application mechanism have become a brand new thinking method and application attempt in the field of cultural advertising creativity.

1. Introduction

The term "cultural and creative industries" first appeared in the 1998 "British Creative Industries Path Document", emphasizing that individuals or teams use technology, creativity, and industrialization to develop, operate, and market industries with intellectual property rights. The main areas of this industry are computers, software, fashion design, advertising, architectural design, animation, music, radio, film and television, the Internet, mobile media, and so on. Our country also put forward the need to vigorously develop cultural and creative industries in the "Outline of the National Cultural Development Plan for the Eleventh Five-Year Plan Period" [1, 2]. At present, the main characteristics of the development of my country's cultural and creative industries are similar programs, products, and content, serious plagiarism in the industry, and insufficient innovation. The government proposed a change from "Made in China" to "Created in China". Since China's reform and opening up, developed countries such as the United States and Europe have taken advantage of intellectual property rights and brands to turn China into their manufacturing plants, paying cheap labor prices and earning high profits on their own, but they consume China's resources. Even at the cost of destroying the environment [3], China has become synonymous with "foundry". Chinese companies have insufficient R&D investment and very limited innovation capabilities. Although some companies have made considerable efforts, most of their products are plagiarism and follow suit. For example, Tencent is already a major Internet company, but the company's business philosophy still believes that "the ability to copy products must be regarded as the company's core competitiveness." Obviously, this society lacks an atmosphere and awareness of innovation. In the communications industry, it is very common for the United States to study Japan and Japan to study Korea. These phenomena are very common. Summarizing the development path of the "cultural and creative industries" in other developed countries, it is not difficult to find that the core of the healthy development of this industry is people, with emphasis on human creativity as the core factor. The information age emphasizes human wisdom, creativity, intellectual property rights, and human proactive factors. Only by giving full play to the active creative factors of people can we lead the development of society in the information age [4–7].

At present, the development of my country's cultural and creative industries can be roughly divided into three echelons. The order is the developed eastern region, the developing central region, and the underdeveloped western region. With the change of the international trend, all countries are actively turning their development vision to the cultural industry. This is an excellent opportunity to build a cultural China, enhance the influence of the world, and enhance the people's recognition of their own culture. China's major cities are also undergoing policy reform, industrial adjustment, and transformation.

The cultural creative industry is a collection of industries that commercialize cultural or natural and human resources with cultural factors through modern technology and creativity. The high-quality development of the cultural and creative industry is concentrated in catalyzing the creation of new business formats, cultivating new kinetic energy, and releasing new vitality, thereby enhancing the core competitiveness of the industry [8]. From the perspective of rapid economic growth to the high-quality stage, labor productivity and total factor productivity have achieved simultaneous increases, which will inevitably promote industrial quality changes, efficiency changes, and power changes. Compared with traditional industries, cultural and creative industries have certain cultural attributes, but also economic attributes such as high technological content, high degree of creativity, high added value, and high degree of integration. Therefore, promoting the high-quality development of cultural and creative industries has rich connotations [9].

The research on creative thinking has a long history, and the creative thinking methods involved are unknown. However, the existing creative thinking methods are more generalized and formalized and lack specific principles to generate creative origins. As an innovative problem-solving theory, TRIZ has good practicability and maneuverability. Try to combine the two, based on the TRIZ principle, seek a breakthrough on the basis of original creative thinking and provide a scientific and efficient cultural and creative industry integration technology. In addition, it provides an application basis for expanding the multifield development of TRIZ theory [10–14].

2. Creative Thinking Method

2.1. The Connotation of Creative Thinking Method. Creative thinking is the creative abstract summary and behavioral potential of the brain's essential attributes and internal connections of objective things. Creative thinking is specifically divided into divergent thinking, convergent thinking, and conversion thinking. Thinking method is the tool and means by which people realize the purpose of thinking through thinking activities. According to different scopes, it can be divided into general thinking methods, specific scientific common thinking methods, and different scientific unique thinking methods. The creative thinking method is a systematic thinking mode, which can be materialized mental activities and high-level expressions. It is a necessary ability to engage in creative thinking activities, and it is the basis of inspiration and behavioral navigation for the completion of creative design. The creative thinking method is constantly changing and evolving.

2.2. The Importance of Creative Thinking Methods. Creative thinking methods play an important role in the design of graphic advertising, enabling designers to give full play to their imagination and creativity, combining good design concepts and artistic skills, combining actual needs and integrating them into their works, thereby enhancing the meaning and communication value of graphic advertising design. Humanistic and artistic value: in the field of design, creative thinking methods are more important than design skills. Especially in today's era, computer software technology is widely used in the field of graphic design. First, the difference between design technologies has become smaller, and the second has prompted more people to chase and update software. The operation technique creates the so-called "designer" who has no ideas, creativity, and mechanical work. Print advertising design urgently needs scientific and creative thinking methods as theoretical guidance and applied to specific design practices. The creative thinking method is not to construct a perfect idealistic plan. Its value is to propose creative, clear, concise, efficient and operable best ideas for the work, thereby increasing the difference between the design and other works and avoiding uninspired ideas, the same while making the viewer experience fresh and intuitive [15].

3. Summary of TRIZ Theory

3.1. The Concept of TRIZ Theory. TRIZ is the abbreviation of English, and its meaning is the theory of solving invention problems. It originated in the Soviet Union. It was the Soviet Genrich Altshuller. After summing up tens of thousands of invention patents, he found that innovation is also regular. Follow his core ideas: first, he believes that no matter what product is a simple or complex system, his core technology must follow objective laws and models to gradually evolve and develop; second, he believes that the driving force for the development of things is due to the technology. Difficulties, conflicts, and contradictions are constantly being resolved; the third is to use as little resources and energy as possible to promote technological breakthroughs and development. The difference between TRIZ theory and traditional innovation methods is that it is a methodology, a summary of laws, and reveals the laws and methods of innovation [16, 17]. This theory has been proven to be correct. For example, the renewal of military systems, equipment, and products in the early Soviet Union was later used by famous companies in the United States, Japan, and other countries. It was discovered that TRIZ's method was used when innovating products. Able to effectively analyze the problem, find the bottleneck and crux of the problem, and quickly grasp the essential problem. It plays a very important role in helping R&D personnel research, break through the fixed thinking, adopt new thinking, summarize the law, and predict the future [18–20].

The most basic three theoretical bases are as follows: (1) in the process of solving problems, people will encounter many contradictions, and corresponding solutions to these contradictions will often appear; (2) there are few innovative ways to solve problems thoroughly, which researchers can learn and master; and (3) generally speaking, the most effective way to solve problems usually comes from some knowledge in other fields. After hundreds of years of development, TRIZ theory has been widely used all over the world.

3.2. The Relevance of TRIZ Theory and Cultural Creative Thinking. Through research, it is found that the research heat of TRIZ theory in innovation is rising. Up to now, TRIZ theory has been developed in many fields such as management science and social science. When people encounter problems that are difficult to solve, they can not only solve them with the knowledge of their own discipline but also use the knowledge of other disciplines to find some solutions in other fields. Therefore, the application of TRIZ theory to cultural and creative industry technology in this paper is consistent [21].

The TRIZ innovation principle is to use the principles and methods of scientific discovery to rationally analyze and thoroughly solve problems. It contains the common principles followed by human innovation and is the earliest, most basic, core, and most practical content of TRIZ theory. It is effective and easy to learn and master, as shown in Table 1.

3.3. TRIZ Innovation Principles and Traditional Creative Thinking Methods. Traditional creative thinking methods are divided into divergent thinking, convergent thinking, and conversion thinking. Divergent thinking is a thinking form in which the brain presents a multidimensional diffusion state. It is a thinking method to put forward abundant ideas and find various ways to solve specific problems from a thinking starting point and break away from traditional practices and create more possibilities. Convergent thinking refers to sublimating logical conclusions from existing representations and gathering broad thinking paths into a focus. It is a convergent thinking mode with scope, direction, and order. The transformation of thinking is to observe objects from different aspects and angles from the perspective of connection and development, to change a new perspective, to avoid stereotypical thinking, and then to get a comprehensive understanding of objects and perfect solutions.

In terms of suitability, logicality, and efficiency of combining TRIZ theory with traditional creative thinking methods, most of the existing creative thinking methods in the field of graphic design, their procedures, steps and measures are based on overcoming psychological barriers of creation to stimulate creative thinking. Its methods are highly abstract and generalized and tend to be formalized [22–24]. TRIZ reveals the inner laws and principles of creation. Compared with traditional creative thinking methods, it adopts scientific methods to boil down particularity problems into general problems of TRIZ and form solutions to problems. In terms of methods and processes of solving problems, TRIZ is faster, more accurate, and more efficient than traditional creative thinking methods. TRIZ is a controllable and effective method and powerful tool for generating innovative thinking from the original origin [25, 26].

Break the inertia, inertia and one-sidedness of thinking, and avoid the blindness and limitation of traditional creative process. TRIZ theory confirms that the basic principles of creativity exist objectively, and these principles can be sorted out and summarized into targeted design creativity theories, which can shorten the design creativity cycle and improve the success rate. To sum up, TRIZ can make up for the obvious deficiencies of the existing creative thinking methods, thus generating a more suitable creative method for design. The design lacks the guidance of innovation theory of rational dimension, while TRIZ can solve problems creatively in a scientific and rational way to achieve design innovation. In order to better grasp the entry point of TRIZ theory in creative thinking, it is necessary to define the TRIZ innovation principle and traditional creative thinking. Among them, TRIZ innovation principle focuses on analyzing the expression law of creative generation from microscopic angle. In contrast, traditional creative thinking focuses on the macro perspective to analyze the general rules of creativity in the process of operation. In the field of combining cultural and creative industries, in addition to the known traditional creative thinking methods, it is necessary to further explore the origin of thinking that can induce its generation. This topic tries to introduce TRIZ theory into the combined field of cultural and creative industry, focusing on the study of modern creative thinking methods based on TRIZ theory.

4. Advertising Culture Creative Industry Technology Based on TRIZ Theory

This article mainly introduces the combination principle, versatility principle, and reverse action principle of TRIZ innovation principle to stimulate divergent thinking, convergent thinking, and conversion thinking in traditional creative thinking and produce methods suitable for creative thinking in advertising. The whole process is guided by rational principles. Thinking, abstract imagination driven by concrete principles, seeks the origin of thinking of the essence of advertising creative design.

4.1. Methods of Using the Principle of Multifunctionality to Stimulate Divergent Thinking

(1) Principle of operation: The famous German philosopher Hegel once said that "creative thinking requires rich imagination". Divergent thinking is listed as the top creative thinking in design.

Table 1: 40 innovative principles of TRIZ theory.

Serial number	Principles of innovation	Specific description
1	Principle of segmentation	1. Divide the whole into independent small parts. 2. Divide the whole into parts that are easy to assemble and disassemble. 3. Improve the separability of the whole and realize the overall transformation
2	Combination principle	1. Spatial dimension, combining the same or similar objects. 2. Time dimension, combining the same or related operations
3	Principle of versatility	1. An object has multiple different functions. 2. Cut objects with unnecessary functions
4	Reverse action principle	1. Turn the object upside down or upside down. 2. Turn the object or the environment into motion and static motion.
...	...	...
40	Principles of composite materials	Replace homogeneous ingredients with composite ingredients

Figure 1: “One World” Figure.

Figure 2: “Symbiosis-building a green city with beautiful China”.

According to the multifunctional principle of TRIZ theory, the principle of using an object to have multiple different functions stimulates the emergence of divergent thinking. A subject has multiple interpretations and an object has multiple uses, which is an important manifestation of the principle of multifunctionality. At any time, place and environment, when objects are versatile, they can have more collaboration and value-added effects.

(2) Application examples: using TRIZ's multifunction principle of "one question with multiple solutions" and "one thing with multiple uses" triggers divergent thinking and produces print advertising creativity. In the creation of the series of print advertisements "One World" shown in Figure 1. The main image is not only the biological representatives of the ocean, land, and sky but also the continents of the world. It not only expresses the biological image but also symbolizes that we live in the same world. The peace and beauty of the world are the theme of our common home. One type of graphic represents multiple content, and the ultimate goal is to express more levels of meaning and connotation. Guided by the same principle, in the creation of the "Symbiosis" theme print advertisement design, as shown in Figure 2. The content of the promotion is to call for environmental protection. The hourglass is used as the main image to convey, indicating that as time passes, glaciers melt, sea level rises, and other issues. Although the current degree is not large, people's real life changes are not easy to detect, but as the time continues to accumulate small problems, they will eventually cause huge problems. The problem, the end point is determined to be a devastating burying of our living environment. The images arouse viewers' deep thoughts. We need to immediately cutoff the problem and pay attention to protecting the environment, otherwise the good life will slowly disappear. The hourglass is treated in a multifunctional way, and its image expresses the double standard of material and time. With the existence of problems and the aggravation of time, small problems will eventually become catastrophic catastrophes.

(3) Summary of experience: The design ideas that have never appeared in the creativity are minimal. The elements that everyone knows are superimposed and synthesized to produce a new image, and then express rich meanings, and they are superior in skills.

Creativity is by no means blindly pursuing the absurd or uncanny. Creativity that comes from the simple elements of life is often the most touching. Using divergent thinking to discover creative points from every bit of life is a corner that is easily overlooked in the creative thinking process. Ensuring the quality of divergent thinking is the basic guarantee for the apparent accumulation of daily knowledge and experience.

4.2. Methods of Using the Principle of Combination to Stimulate Convergent Thinking

(1) Operation principle: The combination principle of TRIZ is to combine the same objects in space or time or objects that complete similar operations. The deconstruction and reorganization of design elements and the introduction of new colors, new textures and new materials into old objects are all important means of the operation of the combination principle, and then the combination principle leads to the aggregation thinking. Such as the complete image split into a single visual elements and repeated distribution in the picture, using the same or similar approach to "processing" one by one, so that the main body repeated and set a certain order, adjust the size of specifications or color texture, the final effect is often able to produce creative and highly visual impact.

(2) Application example: Create print advertising works that promote traditional Chinese folk culture, as shown in Figure 3. First of all, it is planned to use the allusive but well-known positive vocabulary "Hundred Flowers" as the theme to describe culture or literature and use flower patterns as design elements to reorganize the main body in an orderly manner with changes in size, direction, and location. Second, the same noumenon elements are "processed", and the visual element floral cloth representing traditional folk culture is selected to adjust the color and texture of the main body. The shape of blooming flowers and traditional calico patterns imply the beautiful blooming of traditional Chinese folk culture. The finished effect image is full, the meaning is clear, and the visual impact is strong. Figure 4 shows the work "This Cycle," an advertisement for the protection of water resources, which uses clean water droplets and polluted water droplets. After changes in size, color, and texture, they are reorganized in order to form the image of Tai Chi. Tai Chi expresses the process of transformation of all things, and its ultimate goal is to hope that human activities conform to the great virtues and the laws of nature. The emphasis on design elements is gradual, the black and gray water pollution expands, and the blue clean water source decreases. With strong visual contrast, people are called to pay attention to the water cycle, stop water pollution, and keep water clean.

(3) Summary of experience: Convergent thinking uses the TRIZ combination principle as the creative origin in the creative thinking method of print advertising and re-deconstructs and reorganizes the same object into a new image by completing similar operations. Divergent thinking takes the TRIZ multifunctional principle as the origin of creativity and uses the principle of using one object to perform multiple different functions to stimulate new ideas. Convergent thinking and divergent thinking are the

Figure 3: “A Hundred Flowers” theme of traditional Chinese folk culture.

Figure 4: “So Circulation” to protect water resources and public welfare.

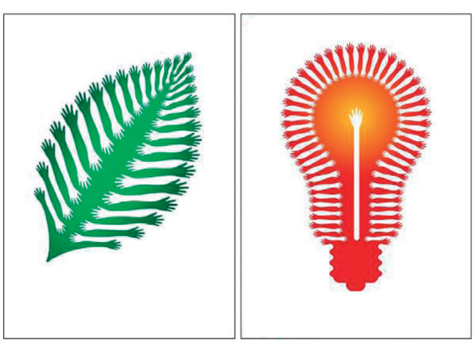

Figure 5: “Request and Rescue” “Utilization and Conservation” energy conservation and environmental protection theme.

Figure 6: Animal protection theme poster.

opposite of the thinking path. These two ways of thinking make a dialectical combination of the expansion and convergence of the creative thinking of print advertising.

4.3. Methods of Using the opposite Principle to Stimulate Conversion Thinking

(1) Operation principle: The opposite principle is a different conventional way to solve the problem and the way of thinking. The application of the opposite principle is to stimulate the transformation of the method of thinking, and the poster design is often simple and powerful, but also can lead viewers into deep thinking. Specific principles include (1) attribute conversion: swap objects with opposite attributes to produce a new image, such as size, speed, and weight; (2) positional and structural transformation: things are arranged in places where they should not appear to change the normal structure of things; (3) process transformation: reverse the natural law of development of things; and (4) theoretical transformation: convey profound meaning and arouse the audience’s resonance and reflection.

(2) Application example: The method of transforming thinking is generated through the opposite principle of TRIZ. The application in the design of graphic advertising can use the principle of the relationship between the positive and negative forms of the main image to cleverly connect the bottom of the picture to complete the composition. This achieves the balance between the visual and psychological spaces of the viewer. Using the same picture to complete the conversion of thinking is not only a conversion of visual thinking but also a conversion of abstract thinking, so that the viewer can get a complete interactive experience and comprehensive cognition. Use the opposite operation path to stimulate the transformation of thinking and create energy-saving and environmentally friendly posters. Take the works “Request and Rescue” and “Utilization and Saving” as examples, as shown in Figure 5, the author cleverly uses the opposite principle and uses the positive and negative patterns of the basic styling elements to convey the theme of the poster. The positive and negative patterns are interdependent and complement to each other. At the same time, it expresses the concepts of claiming, using and saving, and saving. The poster “Extinction” is shown in Figure 6. Using the same method, superimpose the shape of the hand and the pattern of endangered animals. The two sets of different works achieve the same effect, which first activates the viewer’s visual interest, and then promotes the viewer’s deep reflection.

(3) Summary of experience: The most extreme way of thinking in conversion thinking is reverse thinking, that is, thinking about problems from a completely opposite perspective. In the creative thinking of print

advertising, we must dare to go the other way and carry out in-depth exploration of the problem in the opposite direction, which can generate new ideas. Reverse thinking can overcome the solidified deadlock of fixed thinking and inertial thinking.

5. Conclusion

In recent years, the cultural and creative industry has become an emerging industry that countries have vigorously supported and promoted in the new economic era. This article introduces the TRIZ innovation theory into the cultural and creative industry, combined with specific cases, analyzes the creative methods of TRIZ theoretical innovation principles as the origin, stimulates the generation of divergent thinking, convergent thinking, and conversion thinking, and applies it to the creative mechanism and creativity in cultural advertising application. The whole process is guided by rational principles to lead perceptual thinking, and concrete principles drive abstract imagination, exploring the source of thinking of the essence of cultural advertising creative design. This theory and its application mechanism have become a brand new thinking method and application attempt in the field of cultural advertising creativity. Logical analysis verifies the feasibility of combining TRIZ theory with creative thinking. The article mainly introduces TRIZ's combination principle, versatility principle, reverse action principle and divergent thinking, aggregate thinking, and conversion thinking combination mode. The use of thinking in a large number of design practices may not be a simple one-way combination, but may appear in a complex and intersecting form. Therefore, there are still a lot of research vacancies in this topic. In the follow-up research, it should include a large amount of content such as the combination of TRIZ's innovation principle and thinking method and the choice of combination. This article introduces the TRIZ theory into the related fields of advertising creative thinking methods, only to provide a new research field and direction for the future.

As a "content industry" that reflects the national culture of a country, the development of the cultural innovation industry reflects the strength of a country's comprehensive national strength to a certain extent. The emergence of artificial intelligence, a new technology with trans-era significance, has changed the product content form, dissemination form, and consumption mode of the cultural innovation industry. With the continuous development and innovation of artificial intelligence technology, the cultural innovation industry is facing major changes. Therefore, we should constantly explore ways to realize the in-depth integration of artificial intelligence and culture, so that my country's excellent cultural industry can truly integrate into people's lives with the help of intelligent technology, so as to meet the spiritual and cultural needs of the public.

Data Availability

The data set can be accessed upon request.

Conflicts of Interest

The authors declare that they havee no conflicts of interest.

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Research Article

Intelligent Community Management System Based on Big Data Technology

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Community safety has become an important part of social public safety. The construction of a safe community focuses on the accumulation of community safety capabilities. This paper discusses the application of big data technology in community safety construction and the improvement of community safety promotion capabilities. We analyzed the sources and collection methods of community data, classified multisource heterogeneous community data, and constructed seven types of community data. We designed the conceptual structure and storage structure of the community database. On the basis of the construction of the community database, the architecture design of the big data platform for community security was launched. From the perspective of different user types, the functional requirements of the big data platform were analyzed. Combined with demand analysis, the overall architecture design of the community big data platform was carried out. On the basis of the overall architecture, the application architecture and technical architecture were designed in more detail, and the key technologies of the community big data platform were analyzed. Finally, it analyzes how to use the community big data platform to predict public security risks by constructing a CART regression tree model.

1. Introduction

For a long time, the changes in the natural environment and the destruction of man-made factors have intensified the deterioration of the ecological environment in western China, and the contradiction between the environment and development has become increasingly prominent [1]. To protect the ecological environment, while improving the production and living conditions of farmers and herdsmen in the region, starting in the 1990s, with vigorous promotion by the government, the ecological immigration project has been implemented on a large scale in western China [2]. The implementation of ecological migration has played a certain role in improving the local ecological environment and promoting regional economic development. However, for those farmers and herdsmen who voluntarily relocated or were forced, they were faced with both opportunities and challenges. In the process of constructing an immigrant community, there is always some dissatisfaction. At present, safety issues were the most important in the ecological immigrant community [3]. This article will discuss how to improve the safety management of the community and realize the goal of intelligent community management in combination with big data technology.

Yoko Shiraishi of Ritsumeikan University in Japan studied the safety of the elderly under the safe community movement [4]. After analyzing the data of six international safe communities in Japan, she found that the safe community movement has effectively improved community safety. The number of falls and other types of dangerous events has been reduced, which ultimately improves the quality of life of the elderly [5]. Cecilia studied the factors that promoted the sustainability of safe community projects. They believe that safety promotion is different from injury prevention that focuses on technical solutions. Safety promotion tries to influence people's attitudes; to better carry out the sustainable development of safe communities, information exchange is a necessary factor. The safe community needs to provide information to decision-makers, residents, and staff on a regular basis in order to incorporate the safety plan into their daily work; and the cooperation between the safe community and the media is an area that can be improved in the future [6]. Nordqvist et al. established a control group in the communities where safety interventions were carried out and ordinary communities and assessed the safety risk status of children in the two types of communities. The results showed that the risk of injury to children in communities that took safety interventions was significantly lower than that in the control group [6]. Chen and Adefila proposed a higher education participation model for "effective disaster prevention and mitigation education." Research shows the positive impact of college students participating in community "effective disaster prevention and mitigation education" through field trips and internships. In their analysis, they concluded that incorporating "effective disaster prevention and mitigation education" into higher education is beneficial to the community and students. Local higher education institutions should cooperate with local communities to maintain an impact on the sustainable development of society [7]. Barbosa et al. researched and tested and used a data service platform with complex authentication, authorization, logging, and auditing mechanisms. This platform is used to achieve safety assistance and comprehensive care for the elderly in the community. This is to establish a support service platform and a complex safety mechanism that effectively combines the safety management of the elderly in the community, but at the same time, it is also found that the platform still has potential for development in terms of data collection [8].

Today, the world has ushered in the era of "big data." Big data related technologies have become more mature and have been used in many fields. Many scholars study the application of big data in the field of public safety. Scholars design big data platforms, combine and mine urban big data, and then discover new ideas for social public safety governance. The society is also aware of the importance of big data to social development, and the government actively promotes the application and development of big data in various fields [9]. In summary, there are few studies on the application of big data platforms to the construction of community safety. Community security has become the foundation of social security, and big data is also playing an important role in more and more fields, and big data still has a lot of room for development. Therefore, the combination of big data and community security emergency management will be the focus of future research and trends.

2. Construction of Community Management Database

There are many types of data in the community, and there are also many data sources. The first step in establishing a community database is to collect community data, and the basis of collecting community data is to clarify the source of the data and what different types of community data can be collected from these sources. This section will analyze the source of community data.

2.1. Management Department and Organization Data System. The government departments that construct and manage the community have basic information and data in the community, including the basic information of community residents, infrastructure information in the community, construction information, greening information, and so on. The community information data of government departments is the most basic data of the community [10]. Although these data have a certain amount of data and involve many types of data, the content of the data is not detailed, and there is also the problem of timely data updating. The data system of the community property contains the basic information of the owner, the house information, and the information of the cleaning personnel, maintenance personnel, security personnel, and other staff in the community.

The community data in the community construction and management department data system can be used as the basic data of the community big data platform database. Starting from the needs of the platform, these basic data are filtered, cleaned, and stored. However, there are barriers to data sharing with management departments. The construction of community big data platforms must actively cooperate with multiple management organizations to seek data sharing and break the barriers between community data systems [11].

2.2. Equipment Collection Data. Detection and monitoring equipment installed in modern communities collect real-time data on changes in the community. The detection and monitoring equipment can collect the data of the infrastructure equipment in the community, the data of the community residents, the community environment data, and so on, with multiple data types, rich data structures, and the characteristics of real-time data update. The data collected by community detection equipment is an important source of real-time data in the community database. There are mainly the following forms of equipment collection data in the community:

2.2.1. Sensing Detection Equipment. Various sensing devices such as temperature sensors, infrared sensors, and water immersion sensors installed in the community collect dynamic data on the environment, infrastructure, and residents in the community [12]. The data collected by the detection equipment in the community has the characteristics of timely update, and the data reflects the real-time status of the detection object. The data collected by the detection equipment is a powerful support for the daily management of the community, the prediction and prevention of safety accidents, and the emergency decision-making of emergencies.

2.2.2. Video Surveillance Equipment. Video surveillance equipment collects dynamic video, image, and audio data of the movement of people in the community in real time. Face recognition camera collects facial image information of people entering and leaving the community. 3D oblique photography technology collects building house information and outputs 3D video data of community houses after modeling. The community data collected by video monitoring equipment is mainly semistructured and unstructured data. The data is visualized and more intuitive, and it can also realize real-time data collection.

2.2.3. Modern Technology Equipment Such as Drones and Robots. Modern drone technology combines detection equipment and video monitoring equipment to collect data in the community and combines the types and characteristics of data collected by the two types of equipment [13]. Robots patrol the community, collect road information, real-time information on the flow of people, and so on. The community information collected by modern technology equipment can be combined with the characteristics of data collected by multiple devices, including multiple data structures and data types.

2.3. Personnel Collecting Data. The data information collected manually by the community grid members supplement the data that the equipment cannot collect. There are more types of data collected manually, and the data is more detailed. Manual collection has great flexibility. It can check the conditions of equipment, buildings, and environment, communicate with residents, and collect unstructured text information in the community. Manually collected data is an important source of multisource heterogeneous data in community databases.

2.4. Community Safe Data Network. Store the previously data collected in seven types of databases. Data entities in different types of databases are closely linked. Start with a community entity as the center, connect with other data entities, and radiate to the surroundings in a "radiation type." Each data entity can be used as a center to connect other data entities with a radial model [14]. After continuous connection, the data in the community database will eventually form a community data network that is connected as a whole. Figure 1 shows a schematic diagram of the community data network, with residents of a certain community as the center, forming a part of the community data network. The figure shows an example of the data in the local community data network. The data takes people as the main unit and is expressed in a tree-like structure, which is then associated with related items, fire-fighting facilities, and so on.

The community data network makes the community data a whole. The data entity can be described from different angles. For example, the residents of a certain community can be the owner of a house, the owner of a vehicle, the owner of a pet, and the object collected by video information. Establish a "community data cube," that is, "multidimensional" data. Each data is related to different data from multiple angles. In practical applications, according to the type of accidents concerned, take a certain community data as the center, and extract the data related to the accident from the multidimensional associated data [15]. For example, in case of a fire in a household, taking the community resident data as the center, select the associated house data, family data, neighbor data, fire equipment data, sensor data, and so on, and extract and process these fire related data from the community data network, which is conducive to further data analysis and processing.

2.5. Design of Community Safety Database Structure. Community data comes from objective entities that exist in the community, and the community database is a collection of community data. The community database is essentially a study of objective entities in the community and reflects the existing connections between entities. However, the physical forms that exist in reality cannot directly enter the computer. They must be abstracted into data and stored in the computer before they can be recognized, analyzed, and processed by the computer. Conceptual structure design is the process of abstracting real entities into conceptual models [16]. The entity-relationship model (i.e. E-R model) is one of the most commonly used modeling methods for database conceptual models. This section will use the E-R model method to design the conceptual structure of the community database. The main components of the E-R model are entities, attributes, and connections. The specific representation methods are as follows.

(1) The entity is represented by a rectangle, and the entity name is inside the rectangle.

(2) The attribute is represented by an ellipse, and the attribute name is inside the elliptical box, and it is connected to the entity with an undirected edge.

(3) The connection between entities is represented by a diamond, and the connection name is inside the diamond box. The connected entities are connected by an undirected line, and the connection type is indicated on the undirected line. There are three types of contact, one-to-one contact (1:1), one-to-many contact (1:n), and many-to-many contact (m: n).

Taking a fire accident in a house in the community as an example, a fire accident occurs in a house. Multiple residents can live in this house. Multiple firefighting and first-aid equipment are used to participate in fire rescue work. The fire accident will have a harmful impact on residents. Part of the data conceptual model design of the community fire accident is shown in Figure 2. The E-R model diagram shows the conceptual structure and logical relationship of some data.

2.6. The Design of the Storage Structure of the Community Security Database. The community database is a relational database, and there is a logical connection between entity data. Design the data storage structure on the basis of the

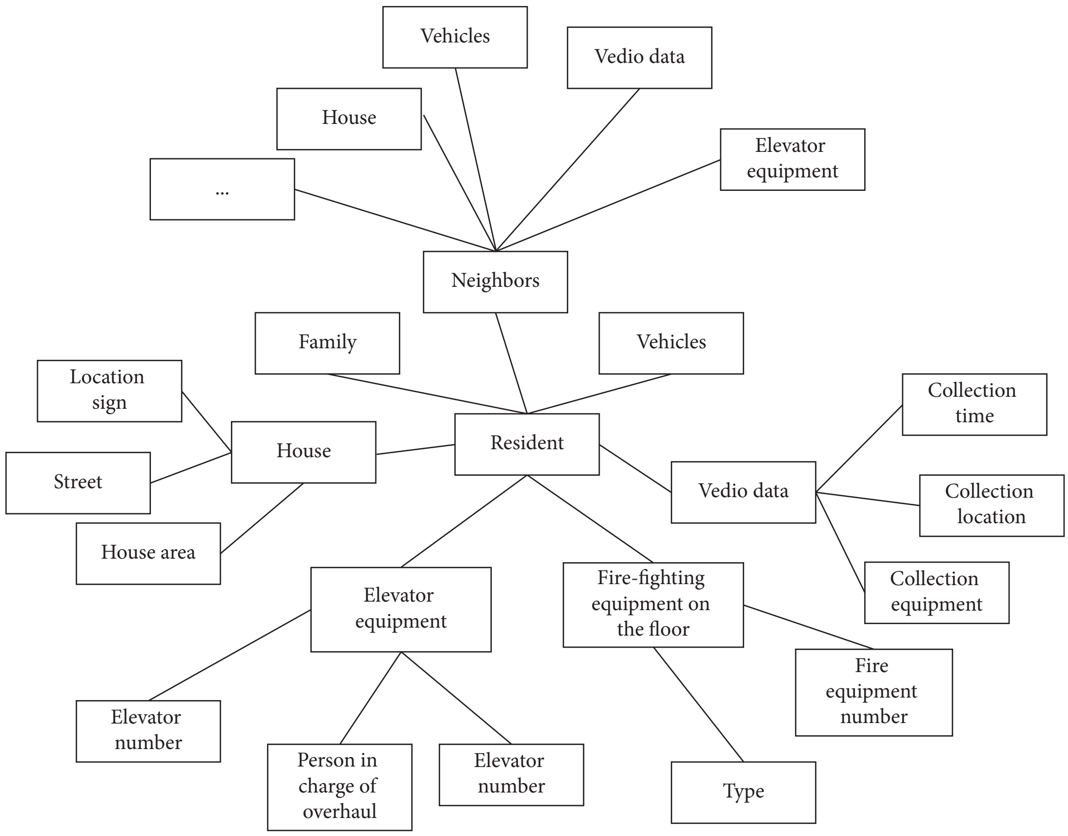

Figure 1: An example of a local community data network.

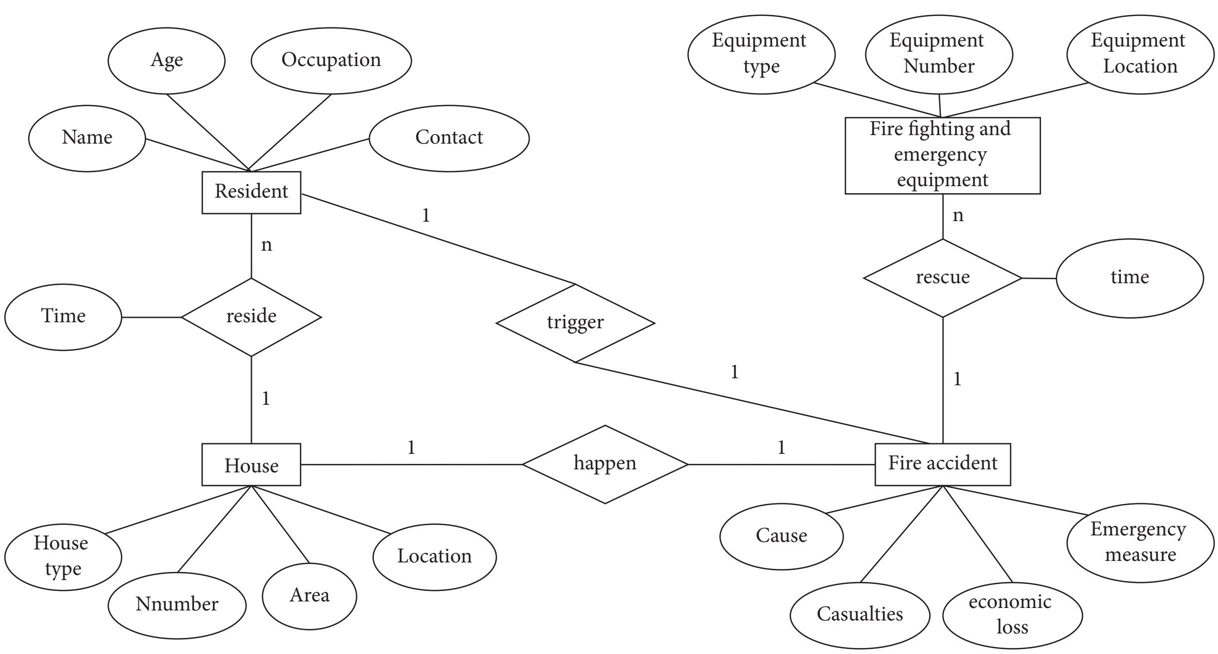

Figure 2: Community fire accident E-R diagram.

data conceptual structure model. Each community entity has a unique code that can identify it in the storage of the database. This code is the entity's identification attribute, such as resident code, house number, equipment number, and vehicle number. Establish the layer table, class table, and detailed attribute table of the community database [17].

The layer table corresponds to seven types of information at the database level, including the entity code, entity name, level information, level code, and other content of the level. The class table corresponds to this class code, entity code, and entity name. The detailed attribute table corresponds to the entity code, entity name, and attribute data of the entity. Take population data in the community as an example. The population data layer table contains the population data layer code. The three types of entity codes are permanent population code, temporary resident population code, and staff code; the permanent population category table contains permanent population code and permanent residents code, permanent resident name, and so on; the detailed attribute table of a resident contains detailed attribute information data, such as resident code, name, occupation, and contact information.

On the basis of the conceptual structure model of the database, the data are connected by a logical relationship. In the stored data table, the tables of each database layer establish a connection. The category code in the layer table is the same as the category code in the category table, and the category code in the category table is the same as the category code in the detailed attribute table, so that the layer table, the category table, and the detailed attribute table can be linked together. Through these connections, the query language of the database can be used to query and call relational data. The level definition of the data table is clear and simple. Different types of tables are connected by code relationships, and the connection path is concise, which improves the processing efficiency of query and call. Take the analysis of accidents in the community as an example. Data entities such as population data, building data, and infrastructure equipment data are all logically connected to the accident. Each entity level table, entity class table, and entity detailed attribute table are connected through entity codes to achieve multilevel data analysis and description of community accidents.

3. Community Big Data Platform Architecture Design

This part develops the architecture design of a community big data platform for community security. The community big data platform is built to realize the functions of community safety management, community risk analysis, and equipment and facility safety monitoring. The construction of the community big data platform facilitates the lives of community residents and the work of community managers, improves community safety capabilities, and reduces community safety risks. Starting from big data, modern technologies such as modern big data mining are used to build smart and safe communities. This part conducts research and analysis from requirements analysis, platform architecture design, and key technologies used.

3.1. Demand Analysis. This article divides the user types of the community big data platform into two categories, including general community residents and community manager users. Demand analysis is carried out separately according to user types.

Community residents' demands on the platform are mainly divided into the following points.

(1) *Basic Data Acquisition.* Residents can obtain public basic information through the data platform. Residents obtain public basic information through the output of the data platform, such as the safe operation and maintenance of infrastructure equipment; video surveillance in public areas; environmental conditions in the community; location and quantity of firefighting equipment. By obtaining this information, residents can master the daily safety situation of the community and quickly make favorable countermeasures in case of emergencies.

(2) *Receive Community Safety Notices.* The big data platform carries out risk analysis and risk assessment on the community through data analysis and mining. Community safety information is sent to residents through the platform. Residents understand community risks and learn safety knowledge through the platform. By receiving safety information, accidents can be effectively prevented.

(3) *Provide Hazard Information.* Residents who find dangerous situations in the community can reflect the situation to the data platform at the first time.

Community safety management is an important part of the management of community managers. Community managers have community safety management needs for the data platform. The main requirements are as follows.

(1) *Community Daily Safety Management.* Community managers obtain community facilities and equipment data, resident data, environmental data, monitoring data, sensor acquisition data, and so on through the platform to carry out daily safety management.

(2) *Community Risk Analysis.* The data platform carries out risk analysis and risk assessment on the community. Knowing the risks existing in the community, managers can timely investigate and manage the community risks, avoid accidents, and improve the safety level of the community.

(3) *Community Data Monitoring.* Through the data collected by sensing detection equipment and video monitoring equipment in the community, the manager can carry out daily monitoring on the facilities and equipment, buildings, and community environment in the community and track and monitor the suspicious people flowing in the community.

(4) *Community Emergency Management.* When an emergency occurs in the community, the manager uses the data platform for emergency management and takes emergency measures for the accident.

(5) *Analysis and Handling of Community Accidents.* After the occurrence of community accidents, process and analyze the accident data, absorb the accident experience, and improve the safety management level and accident emergency level.

3.2. Platform Architecture Design. Using the relevant technologies of big data, build a big data system for community safety, sort out and integrate the community data collected from multiple sources, and design the overall architecture of the community big data platform in this paper in combination with the functional requirements and technical elements of users for the community big data platform. Under the background of big data technology, from the perspective of users, facing community security, real-time processing community structured, semistructured, and unstructured data, so as to realize the data technology intelligence of community security management.

The community big data platform is generally divided into the following parts: data input layer, data storage layer, data processing layer, application access layer, and data output layer. The overall architecture is shown in Figure 3.

For community data collected from different sources, the platform extracts, transforms, and loads the data through ETL technology. After preprocessing the multisource heterogeneous data, the data is stored according to different categories. Hadoop system is used to analyze and process different types of data. According to the functional requirements of platform users, the community data is comprehensively and intelligently analyzed. The results of data analysis can be visually output by means of emergency management platform and mobile terminal.

3.3. Technical Architecture. The technical architecture of the big data platform is divided into five layers:

(1) *Data Collection Layer.* The data collected by various collection methods in the community are processed and imported through ETL technology.

(2) *Distributed Storage Computing Layer.* This layer mainly uses HDFS and other technologies for distributed storage of data, MapReduce, and hive and for distributed calculation and analysis of data, and zookeeper technology for distributed cooperation.

(3) *Interface Layer.* FTP, web service, R language interface, and other technologies will provide interfaces for data transmission.

(4) *Business Application Layer.* This layer will realize the main functional applications of the community big data platform, such as data query, data fusion, data analysis, data matching, and risk analysis.

(5) *Access Layer.* The data platform provides users with visual data output through different terminals, such as mobile terminal, web browsing, community integrated management platform, and so on.

3.4. Data Preprocessing. The multisource heterogeneous data collected by the community through various technical methods shall be preprocessed through ETL technology, such as data extraction, processing, conversion and loading, and the preprocessed data shall reach the data storage and computing layer. The ETL technical workflow is shown in Figure 4. After the system data is integrated with the collected data, data extraction and data cleaning are completed to obtain verification data. Datasets for different purposes are then stored in different locations after matching the dataset to the task.

3.4.1. Data Extraction. The first step of collecting community data is to extract data. The data extraction shall comprehensively determine the extraction rules by considering the data extraction frequency, data update frequency, and other contents based on meeting the needs of users. The data extraction of community data platform shall meet the extraction requirements of structured data, semistructured data, and unstructured data. The frequency of data extraction shall meet the actual needs of real-time updating of community data. The extraction method should include full extraction, incremental extraction, and so on.

3.4.2. Data Cleaning and Processing. The data extracted from different sources will also have problems such as data storage format, data integrity, classification, and import of data types, so it is necessary to carry out subsequent cleaning, conversion, and processing of the data.

Community database is a relational database, and community data has the characteristics of multisource and heterogeneous. Combined with the actual needs of the data platform, the data can be processed in two ways. There are structured community data in the management department data system. This kind of structured data can be processed by SQL statements. This method can be used to convert and process structured data clearly and efficiently. For semistructured and unstructured data, SQL cannot be processed. It needs to be processed in ETL engine to realize data type conversion, data cleaning, data matching query, and so on, according to functional and storage requirements and certain conversion rules.

In addition, due to the different data formats of different data, in order to keep the subsequent data interfaces consistent, the data needs to be aligned. The specific method is to keep different types of data in the same data type and use the long integer format for data storage.

3.4.3. Data Loading. Loading the extracted, cleaned, transformed, and processed community data into the storage computing layer is the last step of community data preprocessing. The formulation of data loading scheme needs to consider the loading efficiency on the basis of meeting the functional application needs of community platform users. Considering a large amount of historical data and real-time dynamic data collected by the community, the community data platform should realize batch data loading. A large amount of data should be loaded into different databases at the same time, and manual loading is supported.

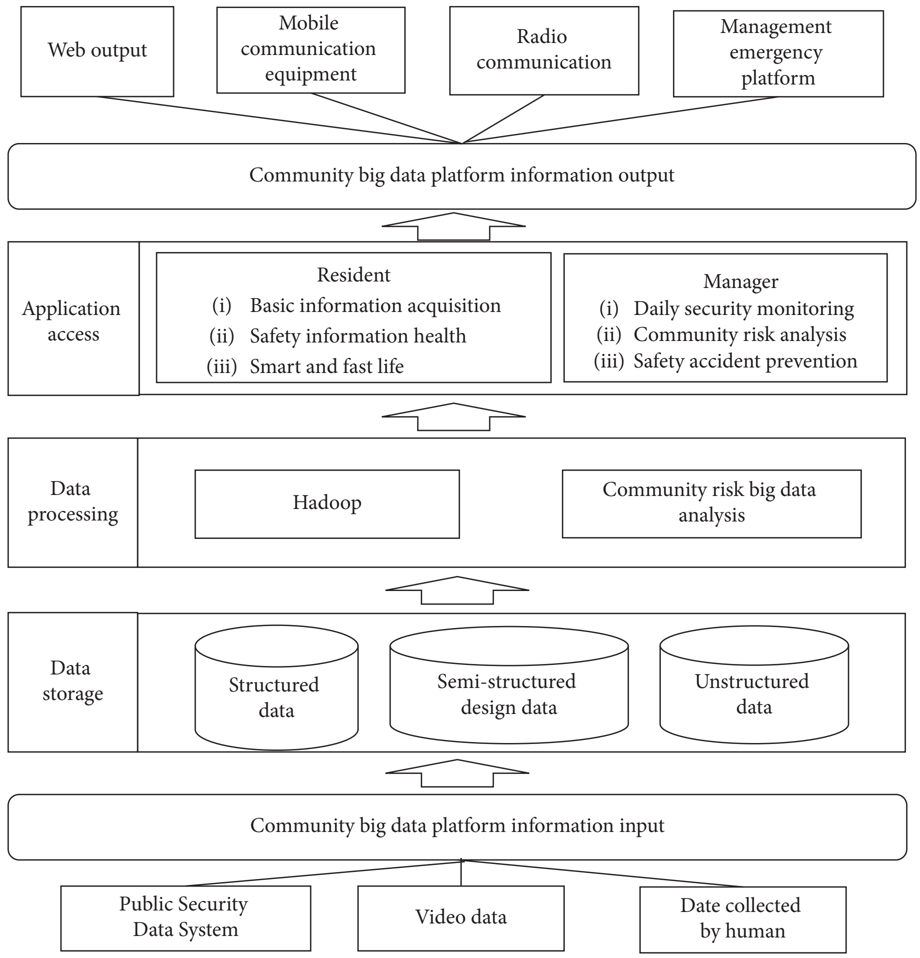

Figure 3: Overall architecture design of community big data platform.

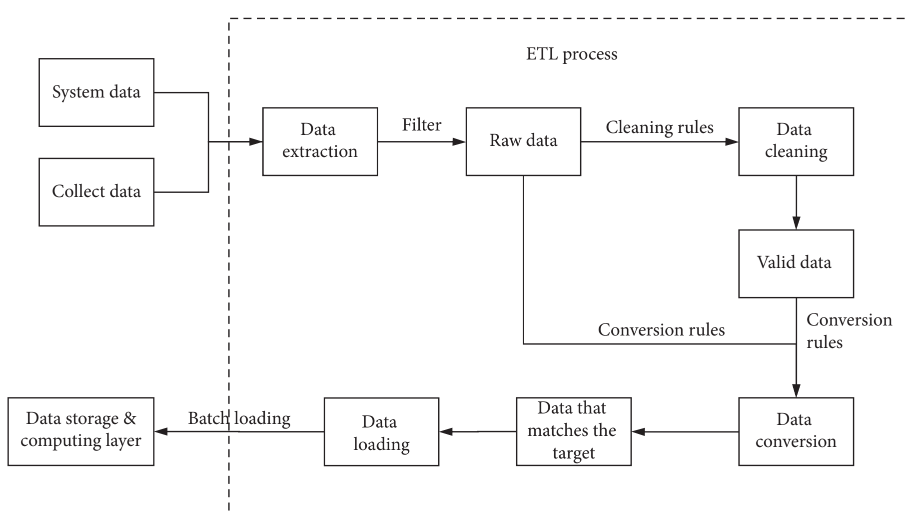

Figure 4: ETL work flowchart.

4. Risk Prediction Based on CART Regression Tree

4.1. CART Regression Tree Construction. When analyzing the factors related to community public security risks, it is found that the characteristic data is basically composed of four categories and a total of 21 attributes. The decision tree can more accurately find the relationship between attributes and classes, and when the relationship is found, it can be used to predict feature data of unknown categories. Therefore, this article chooses to use CART regression tree to build a single model. CART assumes that the decision tree is a binary tree, the values of internal node characteristics are "yes" and "no," the left branch is the branch with the value of "yes," and the right branch is the branch with the value of "no." Such a decision tree is equivalent to recursively bisecting each feature, dividing the input space, that is, the feature space into finite units, and determining the predicted probability distribution on these units, that is, the conditional probability distribution output under the given input conditions.

Since the prediction of future community security incidents based on various risk factors is a numerical prediction, the CART regression tree is used for prediction during the construction of the decision tree model. Figure 5 is the flowchart of the CART regression decision tree algorithm. In the process of model construction, the smallest MSE is selected as the dividing node of the feature data, and the average value of all sample data where the feature data falls into a certain node is used as the output value of the predicted value of community public security cases.

CART regression tree construction process is as follows:

(1) In order to predict the volume of community security cases and verify the accuracy of the model, first, all feature datasets are divided into training sets and test sets. Construct a regression tree training sample set. In the community public security risk data set S, $S = \{(X1, Y1), (X2, Y2), \ldots, (Xi, Yi), \ldots, (Xn, Yn)\}$, where (Xi, Yi) is a single sample in the sample, Xi is a vector constructed according to the data source introduced previously, and Yi is the output target value, which is the predicted volume of community security cases.

(2) Create a root node based on the community public security risk training data sample set constructed in step (1). When there is only one sample left, the node is returned as a leaf node, and when the sample sets corresponding to the root node are all of the same category, the node is also returned as a leaf node, and the predicted value is output.

(3) For each feature predicted by community public security cases, perform a division on the feature and calculate the corresponding segmentation index value. This study uses the mean square error as the segmentation node and first selects a feature data value in the community public security data as a cutting point, calculates the mean square error at this time, and then recursively calculates the mean square error of the remaining characteristic factors of community public security. After traversing all the eigenvalues, compare all the mean square errors, and find the eigenvalue when the mean square error is the smallest is the best cut point for this regression tree.

(4) According to the segmentation index value of the public security risk data in step (3), select the best feature segmentation attribute, and divide the community public security case sample set S into S1 and S2 sample subsets accordingly.

(5) For sample subset S1 and sample subset S2, repeat the process from step (2) to step (3) until the generated regression tree no longer produces new branches.

To prevent the CART regression tree from being divided too finely, it will have an overfitting effect on the noise data in the community public security data, and the CART regression tree is postpruned. If the noise data in the community public security data interferes too much, so that the model has overremembered the noise characteristics but ignores the real relationship between input and output, it must be solved by pruning. Moreover, only after pruning the CART regression tree can the prediction of the CART regression tree in this paper retain the most important community security feature attribute value division. This article divides the community public security case data set into a training set and a test set. A training set is used to form the learned CART regression tree, and a separate test set is used to evaluate the accuracy of the CART regression tree constructed in this article on subsequent data. Using the cost-complexity pruning strategy in postpruning, calculate the surface error rate gain value α of each nonleaf node in the decision tree, find the nonleaf node with the smallest α value, and perform pruning. The calculation formula of α is as follows:

$$\begin{aligned} \alpha &= \frac{R(a) - R(A_a)}{|N_{Aa}| - 1}, \\ R(a) &= r(a) \times p(a). \end{aligned} \tag{1}$$

Here, $|N_{Aa}|$ is the number of leaf nodes contained in the subtree species; $R(a)$ is the error cost when node a is pruned; $r(a)$ is the error rate of node a; $p(a)$ is the data on the error rate of the prediction model accounting for all data Proportion; $R(A_a)$ is the error cost of subtree A_a if the node is not pruned.

Finally, after the CART regression tree prediction model is trained, save the model, and use the CART regression tree prediction model to predict the community security case test dataset. By comparing the prediction value of community security cases predicted by the CART regression tree prediction model with the accuracy of the test set data, the prediction accuracy of the CART regression tree prediction model is calculated.

4.2. Analysis of Results. The feature engineering analysis of the original input data is carried out, and the correlation analysis method is used. It is obtained that the correlation

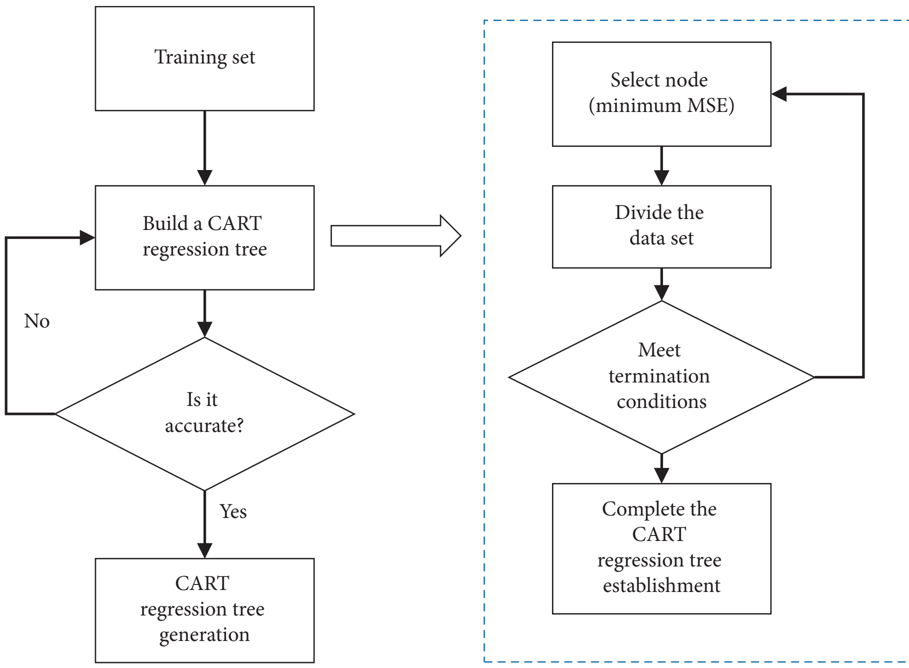

Figure 5: CART regression modeling framework diagram.

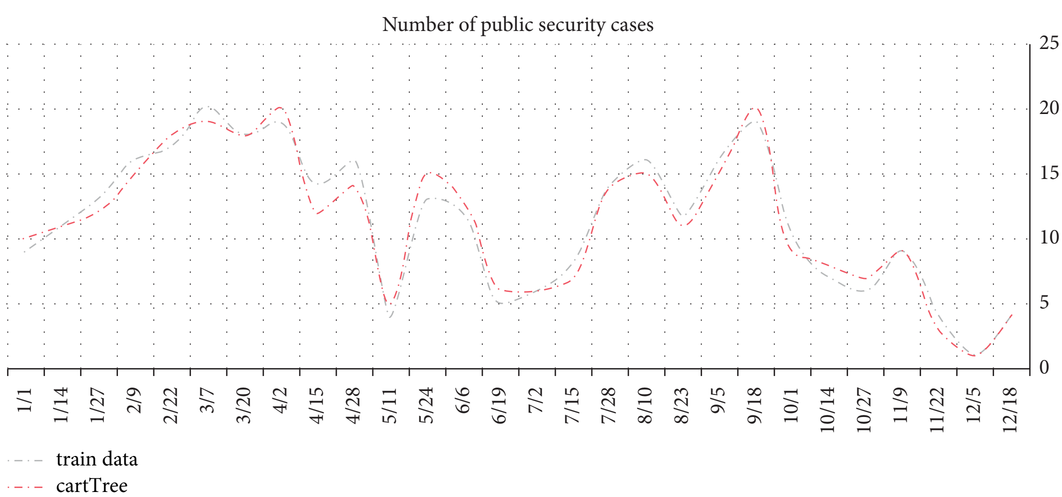

Figure 6: Comparison of cart regression tree model prediction results.

between the data was seven days ago and the target value is 0.978, and the correlation between the data was six days ago and the target value is 0.982. The data obtained seven days ago and the data obtained six days ago are strongly correlated with the target value. To enrich the amount of data, the first seven days of community security cases and the first six days of community security cases are taken as the input characteristics, and the maximum tree depth is 4 and the minimum leaf node is 5.

Figure 6 shows the comparison between the prediction results of CART regression tree prediction model on the test set and the actual observation values. The error between the test data and the predicted data is very small, which shows that the prediction model proposed in this paper is suitable, and also proves the feasibility and effectiveness of the method in this paper. The data takes one day as the granularity, the abscissa is the date, and the ordinate is the number of community security cases. The gray solid line is the actual number of community security cases collected every day in Z community of H City in 2019, and the red solid line is the prediction result of cart regression tree model. It can be seen from the figure that the trends of the gray solid line and the red solid line are basically the same. The two solid lines have two wave peaks and two wave troughs. From the beginning of a year to the first wave trough, the predicted value of the regression tree is much higher than the actual value, but the difference between the predicted value and the actual value after the first wave trough is very small. At the wave peak, the predicted value of the regression tree model is higher than the actual value. At the first trough, the trough value of the predicted value of the regression tree is higher than the actual value, and at the second trough, the predicted value of the regression tree model is lower than the actual value.

5. Conclusion

Facing community security, combined with big data technology, this paper analyzes studies and designs the relevant contents of community big data platform. This paper studies the origin and development of the concept theory of community in China. Using the method of questionnaire survey, this paper studies the relationship between factors such as community safety management and community residents' satisfaction with the community and analyzes residents' attitude towards providing personal data to noncommercial community big data platform. The classification of community database data types was studied, and the community database structure was designed. Based on the community database, this paper summarizes the functional requirements of the community big data platform, then designs the architecture of the community big data platform combined with Hadoop and other big data technologies, and analyzes and studies the key technologies in the platform. Finally, combined with the data in the database, the CART regression tree prediction model is constructed to predict the community public security risk, which provides convenience for the rational scheduling and allocation of community police resources in the future, and provides decision support for the prevention and control of community public security risk.

Data Availability

The dataset can be accessed upon request to the author.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Theory and Numerical Simulation of Deep Rock Mass Based on a Non-Euclidean Model

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Rock masses existing in nature may experience closed internal stress under the action of geological structures. This closed internal stress makes the deformation of the rock mass incompatible, so classic continuum theory is not suitable for analyzing the stress and deformation of rock masses. In this study, a non-Euclidean model for rock masses was established based on differential geometry. By choosing the non-Euclidean parameter as the internal variable, a thermodynamic model was constructed. Then, numerical computation based on the non-Euclidean model was applied to a circular tunnel in a deep rock mass. The distribution of internal stress and the effects of rock parameters on the distribution of internal stress were analyzed. Through our research, we conclude that the stress field of the deep rock mass consists of classical stress and internal stress and that the internal stress shows a distinct wavy behavior. The radius of the fractured zone decreases with an increasing Young's modulus E and Poisson's ratio ν, but increases with increasing non-Euclidean parameter ξ.

1. Introduction

In classical continuum theories of rock mechanics, a rock is a continuous, simply connected body that undergoes deformation, and the deformation satisfies the equations of compatibility. The metric tensor for measuring the distances between material particles in the reference configuration is Euclidean. However, rock masses existing in nature may contain closed internal stress. The internal stress makes the deformation of the rock incompatible. Therefore, the classical continuum theory is not suitable for analyzing the incompatible deformation of rock masses [1–5]. It is necessary to introduce non-Euclidean space to describe the incompatible deformation, and differential geometry will be used to describe the closed internal stress.

The relationship between the continuum theory and mathematical theory of differential geometry has been studied by many researchers. Kondo [6] first recognized the relationship between dislocation theory and non-Riemannian theory. Later, Anthony [7] pointed out the relationship of differential geometry to disclinations. Then, Kroner [8] completed the underlying theory for defects and differential geometry, including dislocations and extra matter. These investigations established a relation between the parameters of non-Euclidean geometry and elastic strain, bend twist, and quasiplastic strain of defect theory [9]. The first non-Euclidean continuum model to describe the stress-field distribution around underground working was developed by Myanikov and Guzev [10]. A modification of this model was presented by Guzev and used to describe different rock phenomena, such as zonal disintegration and anomalous deformation of rock samples [11–15]. Investigations were also undertaken by other researchers, and a non-Euclidean continuum model was proposed to investigate the zonal disintegration phenomenon of surrounding rocks by Zhou and Qian [16–19]. These existing models assume that the undeformed body is in three-dimensional

Euclidean space. However, there is closed internal stress in the rock mass.

Suppose there is a flat plate in two dimensions. Due to uneven heating and mutual expansion, thermal stress will be generated, and the uneven temperature field causes internal stress in the plate. If we cut the whole plate into tiny elements and release each tiny element into its stress-free natural state, then the flat plate composed of various elements can no longer be in two-dimensional Euclidean space. However, if the flat plate is allowed to warp, it will bulge and become a curved surface. The plate is a two-dimensional Riemannian space immersed in three-dimensional Euclidean space R^3. According to this scenario, the undeformed rock mass with closed internal stress should be regarded as a manifold.

In this study, it is assumed that the undeformed rock mass with closed internal stress was a manifold. A non-Euclidean model of rock masses was established based on differential geometry. By choosing the non-Euclidean parameter as the internal variable, a thermodynamic model was constructed. Then, numerical computation based on the non-Euclidean model was applied to a circular tunnel in a deep rock mass. The distribution of internal stress and the effects of rock parameters on the distribution of internal stress were then analyzed.

2. Differential Geometry Method

The initial state of the rock is as a manifold. Moreover, the manifold is an imagined state of undeformed rock that occupies a compact and simply connected region. Consider a material point p in the undeformed body and an m-dimensional manifold M that is referred to as a configuration. We choose the configuration $p \in U \subset M$ at time $t = t0$ as a reference configuration, such that the subsequent deformation and motion of the current configuration are given by $q \in V \subset N$ at time $t = t$ with respect to the reference configuration [14] (Figure 1).

For any $p \in M$, there exists a neighborhood U of p, such that U is homeomorphic to an open set in R^m, i.e., the homeomorphism is φ_U: $U \longrightarrow \varphi_U(U)$.

$$X^i = \varphi_U(p)^i, \tag{1}$$

where X^i is the local coordinate of the point $p \in U$.

For any $q \in N$, there exists a neighborhood V of q, such that V is homeomorphic to an open set in R^n, i.e., the homeomorphism is ψ_V: $v \longrightarrow \psi_V(V)$.

$$x^i = \psi_V(q)^i, \tag{2}$$

where x^i is the local coordinate of the point $q \in V$.

The deformation of the body is a continuous map from the initial configuration smooth manifold M to the final configuration smooth manifold N. F: $M \longrightarrow N$. Compatible coordinate charts (U, φ_U) exist at points $p \in M$ and (V, ψ_V) at $f(p) \in N$, such that the map

$$\psi_V \circ F \circ \varphi_U^{-1}: \varphi_U(U) \longrightarrow \psi_V(V), \tag{3}$$

is C^∞ at the point $\varphi_U(p)$.

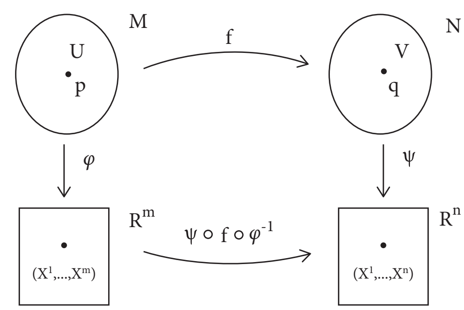


Figure 1: The initial configuration and final configuration. M is the manifold of the undeformed body. N is the manifold of the deformed body.

Moreover, smooth maps F between M and N induce linear maps between tangent spaces and between cotangent spaces. F: $M \longrightarrow N$, $p \in M$, and $q = F(p) \in V$. F_* is a linear map of the tangent space induced by F. We define the map F_*: $T_pM \longrightarrow T_qN$ as follows (Figure 2):

$$F_*(v)(f) = v(f \circ F), \quad \forall f \in C^\infty_{F(p)}. \tag{4}$$

The adjoint map of F_* is $F^*: T_p^*M \longrightarrow T_q^*N$ which is called the differential map induced by F.

$$F^*(df) = d(f \circ F), \quad df \in T_q^*N. \tag{5}$$

X^i and x^i are the local coordinates of points p and q. The deformation map F can be expressed near p by the functions

$$x^\alpha = F^\alpha\left(X^1, \ldots X^m\right), \quad 1 \le \alpha \le n. \tag{6}$$

The increment vector dx of point $q \in N$ in deformed body N belongs to cotangent space T_qN, and the increment dX of the corresponding point $X \in M$ in undeformed body M belongs to tangent space T_pM. They are related by the differential map F^*.

Thus, the action of F^* on the natural basis $\{dx^\alpha, 1 \le \alpha \le n\}$ is given by

$$\begin{aligned} F^*(\mathrm{d}x^\alpha) &= d(x^\alpha \circ \mathrm{F}) \\ &= \sum_1^m \left(\frac{\partial F^\alpha}{\partial X^i}\right) \mathrm{d}X^i. \end{aligned} \tag{7}$$

The matrix representation of F^* in the natural bases dx and dX is exactly the Jacobian matrix $(\partial F^\alpha/\partial X^i)_p$. This relates the infinitesimal line segment $dX \in M$ to the corresponding segment $dx \in N$.

Map F^* plays a role in the coordinate transformation from T_qN to T_pM. Since no material point vanishes, there is an inverse relation for F^*:

$$\mathrm{d}x = F^{*-1}(\mathrm{d}X), \tag{8}$$

where F^{*-1} is the deformation gradient.

A volume element dV in undeformed body M is related to the volume element dv in deformed body N through determinant J of the deformation gradient F by $dv = JdV$.

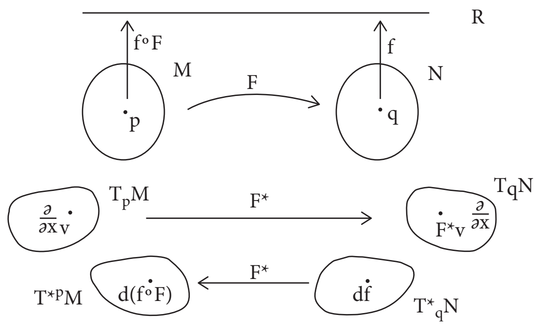


Figure 2: The tangent map and differential map. T_pM and T_qN are the tangent spaces. T_q^*(N) and T_p^*(M) are the cotangent spaces.

$$J = \det F = F^{*-1}F^{*-1}F^{*-1}, \tag{9}$$

where J is referred to as the Jacobian.

The deformed body N is a manifold with a topological structure and smooth structure. During deformation, some vectors act on it, such as body force and external force. They are vector bundles on N (Figure 3).

N is called the base space. π: $E \longrightarrow N$ is a smooth surjective map called a bundle projection, and $V = R^s$ is an s-dimensional vector space.

If there is no mass flux, the total mass of undeformed body M is conserved in deformed body N:

$$\int_M \rho_0 \mathrm{d}v_0 = \int_N \rho \mathrm{d}v, \tag{10}$$

where ρ_0 and ρ are the mass densities before and after deformation, respectively. The time differential form using Reynold's transport theorem gives the following mass conservation law:

$$\frac{\mathrm{d}\rho}{\mathrm{d}t} + \rho\nabla \cdot v = 0, \tag{11}$$

where v is a vector of the tangent bundle and ∇ is the gradient operator. The divergence makes a linear map div: $TM \longrightarrow C^\infty M$.

Newton's second law states that in an inertial frame, the rate of linear momentum is equal to the applied force. Here, by applying the second law to a continuum region, the linear momentum of the deformed body N is given by

$$\frac{\mathrm{d}}{\mathrm{d}t}\int_\Omega \rho v \mathrm{d}v = \int_{\partial\Omega} t \mathrm{d}s + \int_\Omega \rho b \mathrm{d}v, \tag{12}$$

where t is an external force per unit area called the stress vector, which acts on the boundary $\partial\Omega$. It is a tensor of the tensor bundle $T_0^{\,1}(N)$, and the body force per unit volume b acting in volume N is a tensor of tensor bundle TN.

Substituting (12) into (13) yields the following:

$$\rho\frac{\mathrm{d}v}{\mathrm{d}t} = \mathrm{div}\sigma^T + \rho b, \tag{13}$$

where σ is called the Cauchy stress, which gives a transformation law that maps the unit outward n to the traction t acting on the surface by $t = \sigma^T n$. σ is a tensor of tensor bundle $T_0^{\,2}(N)$, and n is a tensor of tensor bundle $T_0^{\,1}(N)$.

Now, we need to measure the extent of deformation of an elemental length located at a material point. To do so, we should introduce a metric on the smooth manifold. If the metric is a smooth, nondegenerate positive symmetric second-order covariant tensor field, then the manifold is called a Riemannian manifold, and the metric is a Riemannian metric. We compare length $|dx|$ with its original length $|dX|$ by comparing the difference of both lengths as a squared measure:

$$|\mathrm{d}x|^2 - |\mathrm{d}X|^2 = g_{ij}\mathrm{d}x^i\mathrm{d}x^j - G_{\alpha\beta}\mathrm{d}X^\alpha\mathrm{d}X^\beta, \tag{14}$$

where g_{ij} is the metric tensor of manifold N, and $G_{\alpha\beta}$ is the metric tensor of manifold M.

Substituting the deformation gradient yields

$$\begin{aligned}|\mathrm{d}x|^2 - |\mathrm{d}X|^2 &= g_{ij}\mathrm{d}x^i\mathrm{d}x^j - G_{\alpha\beta}F_i^{*\,\alpha}F_j^{*\,\beta}\mathrm{d}x^i\mathrm{d}x^j \\ &= \left(g_{ij} - G_{\alpha\beta}F_i^{*\,\alpha}F_j^{*\,\beta}\right)\mathrm{d}x^i\mathrm{d}x^j.\end{aligned} \tag{15}$$

Then, the deformation measure can be written as

$$g_{ij} = 2\varepsilon_{ij} + G_{ij}. \tag{16}$$

This tensor ε is referred to as a strain tensor.

Furthermore, M and N are two smooth manifolds, and f: $M \longrightarrow N$ is a smooth map. If f is the immersion and h is a Riemannian metric, then

$$g = f^* h. \tag{17}$$

where g is the Riemannian metric of M. (17) indicates that the metric of manifold M can be induced by the differential map and the metric of manifold of N.

The Riemann tensor R of the initial configuration is a function:

$$R_{ijkl} = \frac{1}{2}\left(G_{ik,jl} + G_{il,jk} - G_{il,jk} - G_{jk,il}\right) + \widetilde{\Gamma}_{h.ik}\widetilde{\Gamma}^h_{jl} - \widetilde{\Gamma}_{h.il}\widetilde{\Gamma}^h_{jk}. \tag{18}$$

The Riemann tensor R of the current configuration is a function.

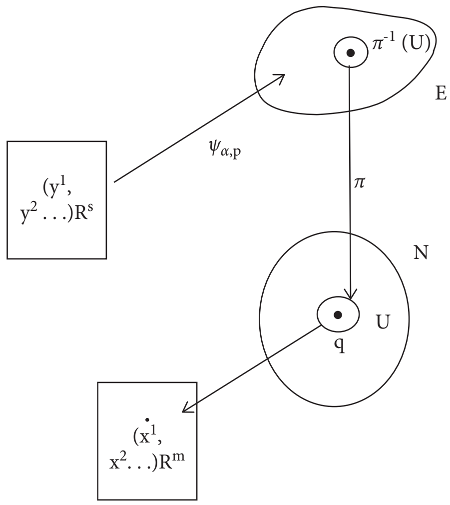


Figure 3: Vector bundles on the manifold. E and N are the smooth manifolds. E is a vector bundle on N.

$$R_{ijkl} = \frac{1}{2}\left(g_{ik,jl} + g_{il,jk} - g_{il,jk} - g_{jk,il}\right) + \Gamma_{h.ik}\Gamma^{h}_{jl} - \Gamma_{h.il}\Gamma^{h}_{jk}. \tag{19}$$

Substituting (18) and (16) into (19), equation (19) can be rewritten as

$$R_{ijkl} = \left(\varepsilon_{il,jk} + \varepsilon_{jk.il} - \varepsilon_{ik,jl} - \varepsilon_{jl,ik}\right). \tag{20}$$

During excavation in a deep rock mass, a circular tunnel is a typical plane strain problem. Thus, the Riemann tensor R can be obtained in a two-dimensional manifold as

$$R_{1212} = 2\frac{\partial^2 \epsilon_{12}}{\partial x^1 \partial x^2} - \frac{\partial^2 \varepsilon_{11}}{\partial x^2 \partial x^2} - \frac{\partial^2 \varepsilon_{22}}{\partial x^1 \partial x^1}. \tag{21}$$

The other component of R_{ijkl} is equal to 0. On the right of (21) is the compatible condition of classical mechanics. Due to the existence of closed internal stress, the deformation of rock masses is not compatible. Then, the tensor contraction of R_{ijkl} is a second-order tensor R_{ij}, and the components are

$$R_{ij} = \begin{vmatrix} \dfrac{R}{2} & 0 \\ 0 & \dfrac{R}{2} \end{vmatrix}, \tag{22}$$

where R is the tensor contraction of R_{ij}, and $R = 2R_{1212}$.

3. The Thermodynamics Model and Discussion

Classical thermodynamics provide valuable information that can assist in the solving of practical problems in many fields of science and engineering. The physical state of the system can be described by variables such as internal energy, entropy energy, and free energy. They are decided by independent parameters; these parameters are the internal variables. The choice of the internal variables is not unique. It can be decided by the level of the model, the nature of the thermodynamic system, and the accuracy of the system state. The independent parameters consist of external variables (the strain tensor, deformation gradient, and temperature) that can be observed and internal variables that relate to the material properties of the system.

In geotechnical engineering, the strain tensor ε, temperature T, and Riemann tensor R_{ij} can be chosen as external and internal variables. Now, we consider the deformation from the initial configuration to the final configuration, and this deformation is elastic. Thus, the Helmholtz free energy can be rewritten as

$$\dot{\Psi} = \frac{\partial \Psi}{\partial T}\dot{T} + \frac{\partial \Psi}{\partial \epsilon_{ij}}\dot{\varepsilon}_{ij} + \frac{\partial \Psi}{\partial R_{ij}}\dot{R}_{ij}. \tag{23}$$

According to the second law of thermodynamics, the Clausius–Duhem inequality will be

$$\rho\dot{T}\left(\frac{\partial \Psi}{\partial T} + s\right) + \rho\frac{\partial \Psi}{\partial \epsilon_{ij}}\dot{\varepsilon}_{ij} + \frac{\partial \Psi}{\partial R_{ij}}\dot{R}_{ij} - \sigma_{ij}\dot{\varepsilon}_{ij} + \frac{q}{T}\,\mathrm{div}, \quad T \le 0, \tag{24}$$

where ρ is the density of the body, s is the entropy, q is the heat flux, and σ_{ij} is the Cauchy stress tensor. The inequality above will be satisfied for any T, Q, h, and ε. Then, the following thermodynamic restrictions hold true:

$$\sigma_{ij} = \rho\frac{\partial \Psi}{\partial \epsilon_{ij}}, \tag{25}$$

$$\frac{\partial \Psi}{\partial R_{ij}}\dot{R}_{ij} + \frac{q}{T}\,\mathrm{div}, \quad T \le 0, \tag{26}$$

$$s = -\frac{\partial \Psi}{\partial T}. \tag{27}$$

Equation (25) indicates that the stress tensor is equal to the derived free energy, in accordance with classical elasticity theory.

Supposing that the rock material is isotropic at a constant temperature, we can extend the free energy to second order with

$$\Psi\left(\varepsilon_{ij}, R_{ij}\right) = \frac{\lambda\left(\varepsilon_{kk}\varepsilon_{kk}\right)}{2} + \mu\varepsilon_{ij}\varepsilon_{ij} + \frac{\nu\left(R_{ij}R_{ij}\right)}{2} + \xi\varepsilon_{ij}R_{ij}, \tag{28}$$

where λ and μ are Lame's constants, and ν and ξ are the parameters related to the internal structure of the rock. Substituting equation (28) into (25) gives

$$\sigma_{ij} = \lambda\varepsilon_{kk}\delta_{ij} + 2\mu\varepsilon_{ij} + \xi R_{ij}. \tag{29}$$

The underground rock experiences the effects of construction and heat, and the deformation will be incompatible and lead to a nonuniform stress field. A part of the stress will be lost by the tunnel excavation, but the residual will remain in the rock. In equation (29), for the initial undeformed body, the strain tensor is equal to zero. Then, the rock experiences an initial stress ξR_{ij}, which is the self-balancing stress closed in the rock. This value is related to the metamorphic and tectonic movement of rock. From a physical point of view, the existence of nonzero self-equilibrated stress fields in a continuous medium is due to the presence of structural defects in the material.

The stress can be regarded as the sum of classical stress Σ_{ij} and t_{ij}:

$$\sigma_{ij} = \Sigma_{ij} + t_{ij}. \tag{30}$$

According to the principles of thermodynamics with internal state variables, we define the force Q as

$$\begin{aligned} Q &= -\frac{\partial \Psi}{\partial R_{ij}} \\ &= \nu R_{ij} + \xi \varepsilon_{ij}, \end{aligned} \tag{31}$$

where Q is a generalized force conjugated to R, which is an internal variable that relates to the internal stress of the rock mass and contributes to the dissipation of energy.

Recall that equation (29) can be written as

$$\varepsilon_{ij} = \frac{1}{2\mu}\left(\sigma_{ij} - \lambda \varepsilon_{kk}\delta_{ij} - \xi R_{ij}\right). \tag{32}$$

For the deformation from the initial configuration to the final configuration, the equilibrium and boundary conditions are

$$\sigma_{ij,j} = 0. \tag{33}$$

Substituting (32) and (33) into (21), we obtain

$$R = \frac{2(\lambda + \mu)}{\mu(3\lambda + 2\mu)}\Delta\sigma_{kk} - \frac{\lambda + 2\mu}{2\mu(3\lambda + 2\mu)}k\Delta R. \tag{34}$$

Because the stress of the rock mass is self-balanced, $\Delta\sigma_{kk} = 0$. Equation (34) can be rewritten as

$$\Delta R + \omega R = 0, \tag{35}$$

where $\omega = 2\mu(3\lambda + 2\mu)/(\lambda + 2\mu)\xi$. Equation (44) is Poisson's equation, and the solution is

$$R = AJ_0(\sqrt{\omega}\rho) + BY_0(\sqrt{\omega}\rho), \tag{36}$$

where J_0 and Y_0 are the Bessel function and Neumann function, respectively. A and B are the parameters related to the structural defects of the material.

Considering a circular tunnel in the plane strain state, the total stress can be written as

$$\sigma_r = p_0\left(1 - \frac{r_0^2}{r^2}\right) + \xi AJ_0(\sqrt{\omega}\rho) + \xi BY_0(\sqrt{\omega}\rho), \tag{37}$$

$$\sigma_\varphi = p_0\left(1 + \frac{r_0^2}{r^2}\right) + \xi AJ_0(\sqrt{\omega}\rho) + \xi BY_0(\sqrt{\omega}\rho). \tag{38}$$

The rock mass experiences gravitational stress and internal stress before excavation. The construction of underground engineering projects breaks the stress balance, and so, the stress will redistribute. In the plane strain state, the shear stress of the internal stress dissipates with the deformation, but normal stress still exists in the rock mass and shows a periodic change with radius. If this stress reaches a critical value, the rock will break.

4. Analysis Based on Numerical Computations

4.1. The Distribution of Internal Stress around a Deep Tunnel. The model for numerical computation [20–23] was from Tangkou mine coal, Shandong Province, China. During the excavation of the tunnel, the completed roadway was damaged successively, and the surrounding rock was fractured violently. The material parameters used in the simulations were from a depth of 1028 m, including a uniaxial compressive strength of rock $\sigma_c = 35$ MPa, Young's modulus $E = 30$ GPa, and Poisson's ratio $\nu = 0.25$. The cross-section of the tunnel is approximately a circle, and the radius is $r_0 = 3$ m. The stress of the surrounding rock is equivalent in vertical and horizontal orientations, and the stress $p_0 = 23.4$ MPa.

Substituting these parameters into equations (37) and (38), we can obtain

$$\sigma_r = 23.4\left(1 - \frac{9}{r^2}\right) + \xi AJ_0(3\sqrt{\omega}) + \xi BY_0(3\sqrt{\omega}), \tag{39}$$

$$\sigma_\varphi = 23.4\left(1 + \frac{9}{r^2}\right) + \xi AJ_0(3\sqrt{\omega}) + \xi BY_0(3\sqrt{\omega}). \tag{40}$$

The parameter ξ is related to the internal stress of the rock mass and can be chosen by the radius of the fracture zone. According to geological observations, the fracture zone radius $r_c = 1.58\ r_0$; thus, we have the following boundary conditions for the function R:

$$R|_{r=r_0} = 0 \cdot \frac{dR}{dr}|_{r=r_c} = 0. \tag{41}$$

Substituting (36) into (41) gives

$$AJ_0(3\sqrt{\omega}) + BY_0(3\sqrt{\omega}) = 0, \tag{42}$$

$$\sqrt{\omega}\left[AJ_1(4.74\sqrt{\omega}) + BY_1(4.74\sqrt{\omega})\right] = 0. \tag{43}$$

By solving equations (42) and (43), $\omega = 7.18$ and $\xi = 5.57$ GPa can be obtained.

Meanwhile, fracture appears when the stresses in the rock mass reach a certain critical value. From a physical viewpoint, this means that it is necessary to use a force criterion, whose fulfillment in a selected region corresponds to the fracture zone. In this study, the Mises criterion is applied.

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\sigma_c^2. \tag{44}$$

Substituting (39) and (40) into (44), we obtain $A = 5.05 \times 10^{-3}$ and $B = 3.57 \times 10^{-3}$. Thus, the relation between the stress components and radius is shown in Figure 4. The distribution of hoop stress and radial stress shows a distinct wavy behavior. The range of fluctuation reflects the magnitude of internal stress and is related to in situ stress and rock behavior.

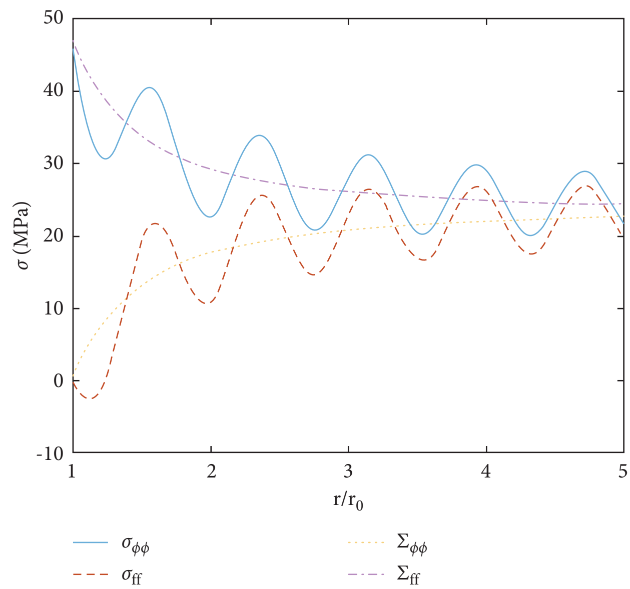


FIGURE 4: The distribution of stress with radius (r).

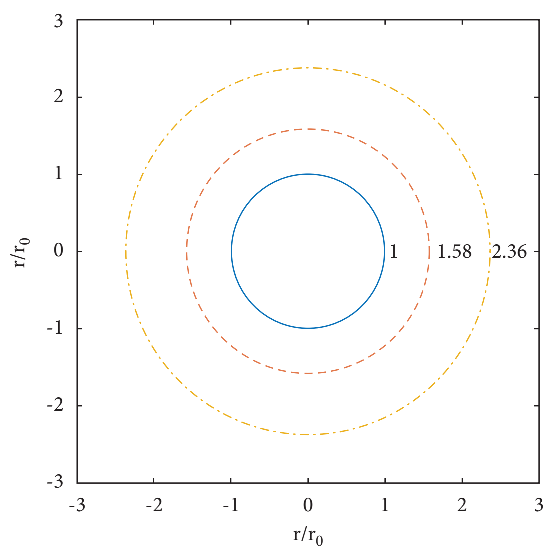


FIGURE 5: The site of crest zones from the computational model. Effects of rock parameters on the distribution of internal stress.

TABLE 1: Location of crest internal stress in the surrounding rock mass.

Location of crest stress (r/r_0)	Young's modulus E (GPa)			Poisson's ratio ν			Non-Euclidean parameter ξ (GPa)		
	27	30	33	0.2	0.25	0.3	5.01	5.57	6.13
First	1.69	1.58	1.47	1.63	1.58	1.46	1.43	1.58	1.67
Second	2.37	2.36	2.02	2.29	2.36	2.06	2.01	2.36	2.34

According to the prediction of the numerical computation, the second crest of the stress is located at 2.36 r_0, and the observation value is 1.58 r_0, as shown in Figure 5. The prediction value is 31% greater than the observation value because the fracture of the rock mass at $r = r_c$ is a region failure.

The fluctuation location and magnitude of the internal stress were influenced by the parameters of the rock mass, such as Young's modulus E, Poisson's ratio ν, and non-Euclidean parameter ξ, which affected the fracture zone of the surrounding rock of the tunnel, and the location of the crest stress is given in Table 1.

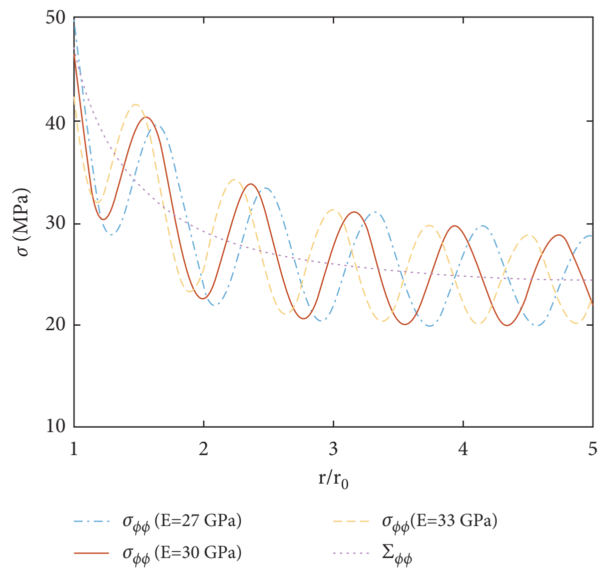


Figure 6: Effects of Young's modulus (E) on the distribution of hoop normal stress in surrounding rock mass.

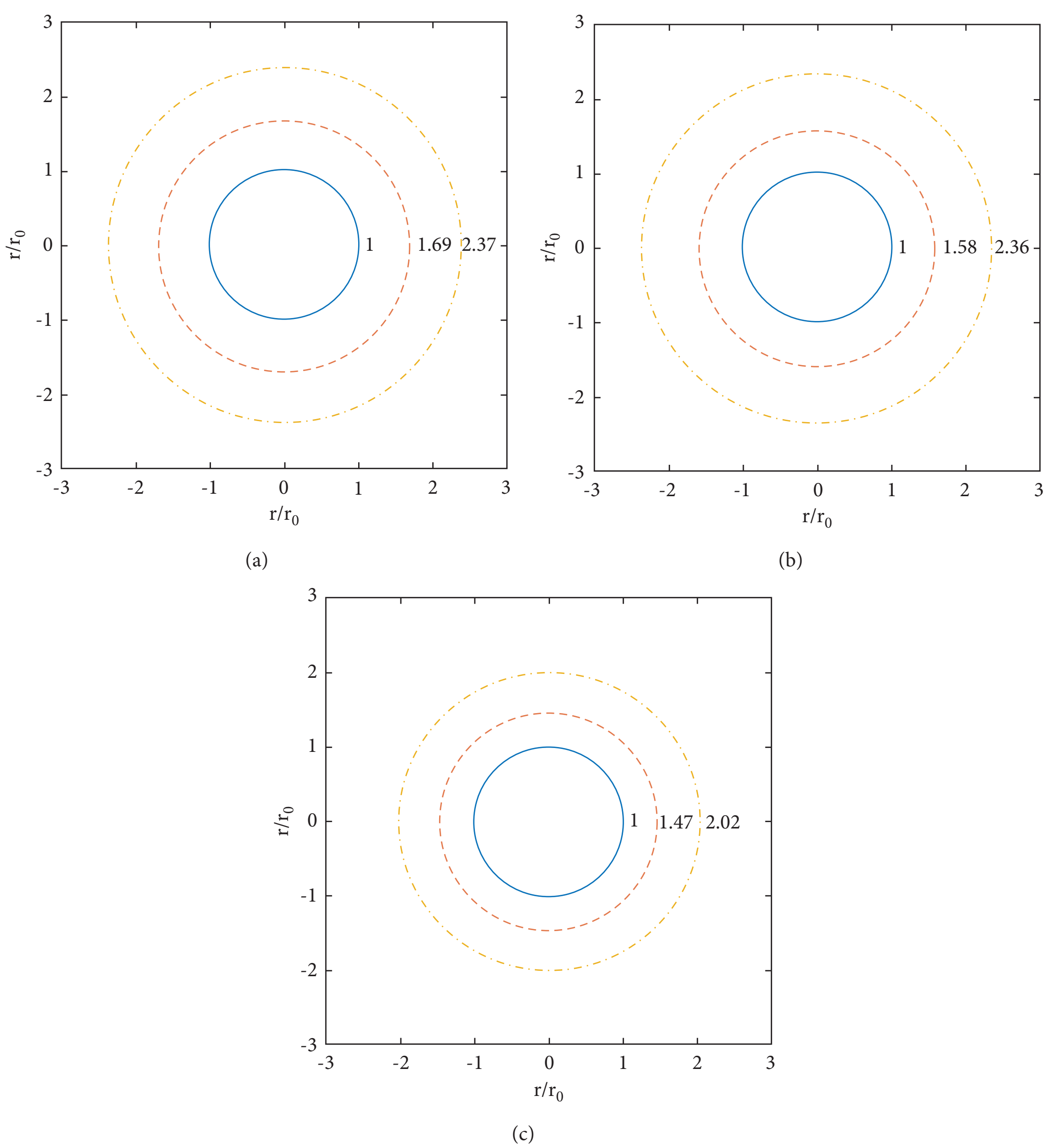


Figure 7: Location of crest internal stress in the surrounding rock mass with different Young's moduli. (a) $E = 27$ GPa. (b) $E = 30$ GPa. (c) $E = 33$ GPa.

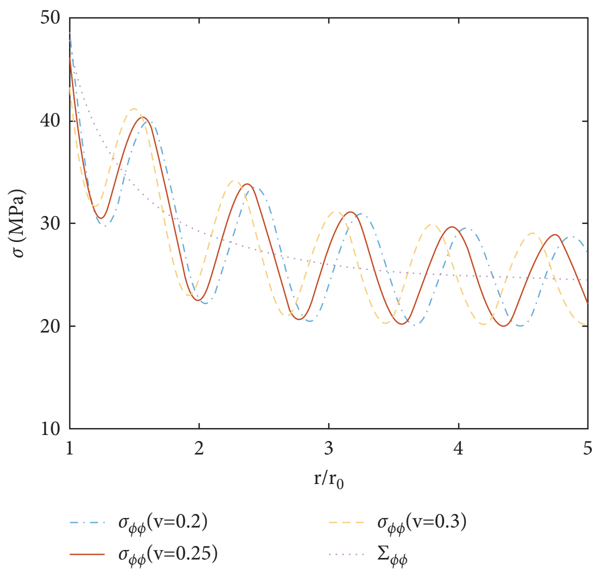


FIGURE 8: Effects of Poisson's ratio (v) on the distribution of hoop normal stress in the surrounding rock mass.

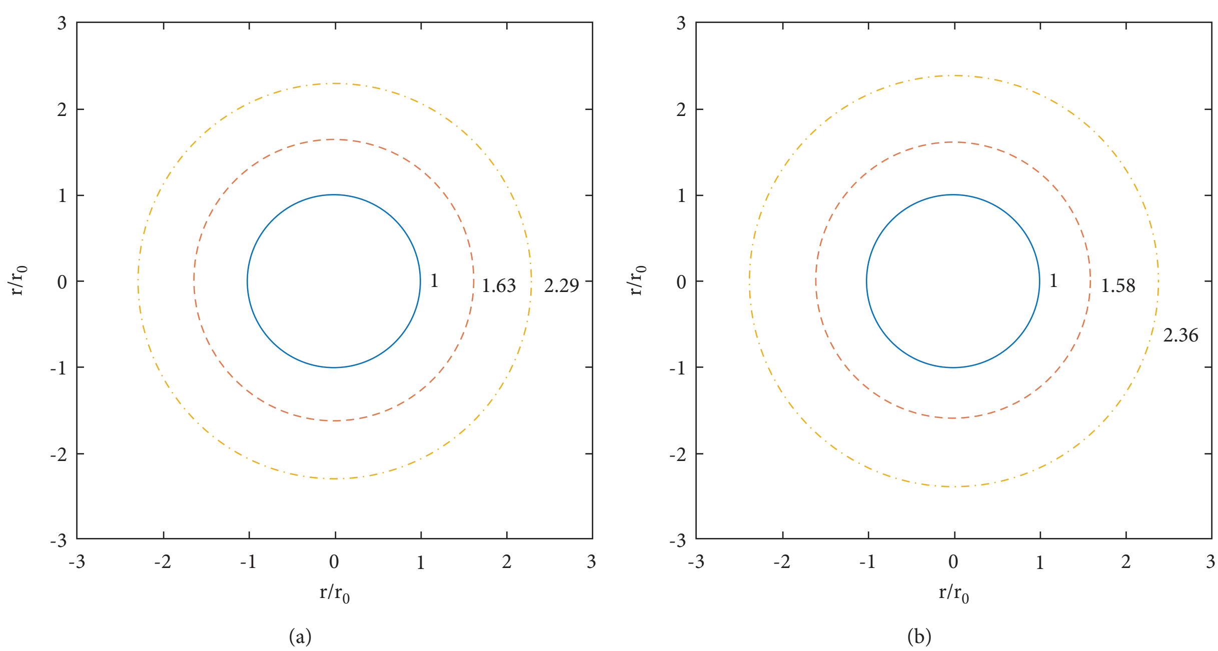
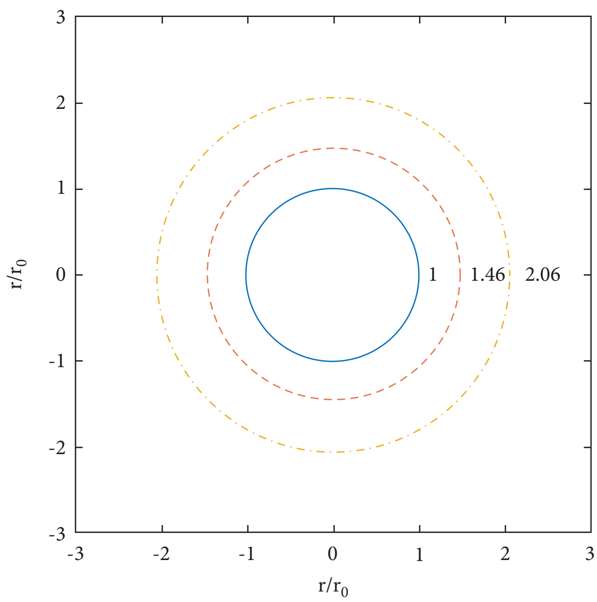


FIGURE 9: Continued.



(c)

Figure 9: Location of crest internal stress in the surrounding rock mass with different Poisson's ratios. (a) $\nu = 0.2$. (b) $\nu = 0.25$. (c) $\nu = 0.3$.

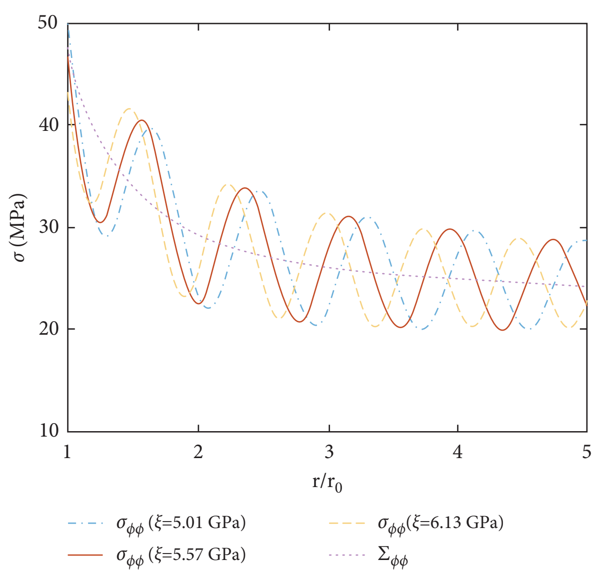


Figure 10: Effects of the non-Euclidean parameter ξ on the distribution of hoop normal stress in surrounding rock mass.

Figures 6 and 7 show the effects of Young's modulus E on the distribution of the internal stress crest in the surrounding rock mass around a deep circle tunnel. It can be observed that the radius of the internal stress crest decreases with an increase in Young's modulus E. These results indicate that the magnitude of internal stress and energy existing in the rock mass increases with Young's modulus. The larger Young's modulus is, the closer the fracture location is to the tunnel.

Figures 8 and 9 show the effects of Poisson's ratio ν on the distribution of the internal stress crest in the surrounding rock mass around a deep circle tunnel. The radius of fractured zones decreases with an increase in Poisson's ratio ν.

Figures 10 and 11 show the effects of the non-Euclidean parameter ξ on the distribution of the internal stress crest in the surrounding rock mass around a deep circle tunnel. It can be observed that the radius of

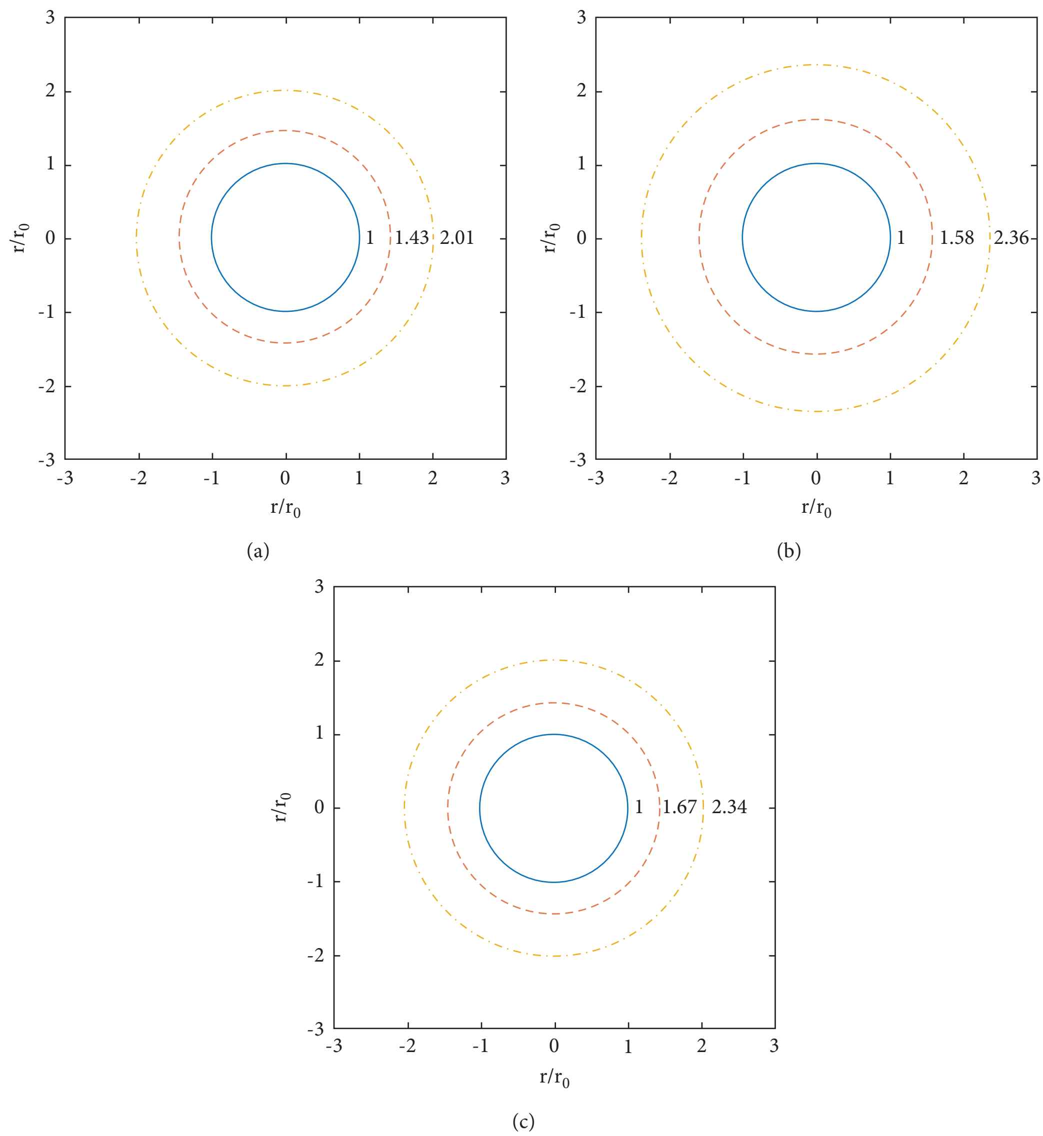


Figure 11: Location of the crest internal stress in surrounding rock mass with different non-Euclidean parameters. (a) $\xi = 5.01$ GPa. (b) $\xi = 5.57$ GPa. (c) $\xi = 6.13$ GPa.

fractured zones increases with an increase in the non-Euclidean parameter ξ.

5. Conclusions

(1) Because there is closed internal stress in the rock mass, the deformation of the rock mass is incompatible. The undeformed body is a manifold immersed in three-dimensional Euclidean space. The metric tensor of the space is the Riemannian metric g_{ij} instead of the Euclidean metric δ_{ij}. The deformation of the rock mass is a continuous map from the undeformed manifold M to the deformed manifold N. The incompatible deformation of the rock mass is related to the Riemannian curvature tensor R_{ijkl} of the manifold.

(2) The rock mass experiences gravitational stress and internal stress before excavation. The construction of underground engineering projects breaks the balance, and the stress will redistribute. In the plane strain state, the shear stress of the internal stress dissipates with the deformation, but normal stress still exists in the rock mass and shows a periodic change with radius. If this component reaches a critical value, the rock will break.

(3) For the rock mass with internal stress, with the increase of elastic modulus E, the peak value of hoop

stress decreases, and the position of peak stress is closer to the tunnel. It shows that the harder the rock mass is, the more severe the damage near the tunnel surface is. With the increase of Poisson's ratio v, the hoop stress of rock mass decreases, which indicates that the larger Poisson's ratio v is, the larger the deformation of rock mass under the same confining pressure, and more internal stress will be released. With an increase of non-Euclidean parameter ξ, the radius of the fractured zone decreases.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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Research Article

System Dynamics Model for Systematic Evaluation of China's Financial Risk

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Finance is becoming more important in the national economy. Maintaining financial stability is critical not only for the financial industry's prosperity and development, but also for a country's political, economic, and social development. This paper will look at the mechanisms that cause systemic risk to develop and evolve, as well as how to measure systemic financial risk in multiple dimensions. To begin, create a system for evaluating financial risk in a systematic manner. Second, using the AHP and CRITIC methods to determine various indicators and market weights, create a systemic financial risk evaluation model based on the system dynamics model, and calculate the system from 2010 to 2019 comprehensive financial risk index. Finally, simulation research is conducted using the system dynamics model of systemic financial risk, and the simulation results are analyzed. The findings show that China's financial risk has been gradually increasing since 2016, with relatively small fluctuations in risk state.

1. Introduction

Systemic financial risks not only occur in financial markets, but also affect macroeconomic and social wealth, according to international social practice [1]. Financial globalization will, without a doubt, benefit China's financial industry. It has the potential to introduce more efficient and diverse funds, introduce international advanced management concepts and innovative thinking, and revitalize China's financial system. However, there are no benefits on either end, and financial globalization has numerous drawbacks [2, 3]. It may increase a country's economy's risk exposure and the financial system's vulnerability to external pressure, raising the possibility of systemic financial risks. Overall, the financial system's operation has a twofold impact on economic development [4]. It has the potential to boost economic growth while also increasing the likelihood and severity of systemic financial risks escalating into financial crises. As a result, systemic financial risk research is particularly important at this stage.

Studies have not designed scenarios for systematic financial risk early warning, but there are differences in systematic financial risk monitoring and early warning under different scenarios [5, 6]. In these studies, empirical research is the majority, while theoretical research is the minority. In empirical research, empirical research on fundamentals and trade channels is the majority, while relatively few focus on financial channels and expectations [7, 8]. Scholars in China have gradually focused their attention on financial contagion research, but due to a lack of data sources and theoretical mechanisms, the existing research results are mostly broad theoretical introductions, with little in the way of specific path analysis and empirical testing of financial risk contagion mechanisms [9–11]. The system dynamics model is used in this paper to investigate the systematic financial risk early warning mechanism of internal driving mechanism. The interaction of these influencing factors (the product interaction term in the econometric model) is used to identify the systematic financial risk on this basis.

A typical system model for the processing and analysis of highly nonlinear [12] and large-scale complex problems is [14] the system dynamics model [13]. We can simulate the real system and find the target problem's solution strategy by establishing a dynamic simulation model. The vast and multilevel structure of the financial ecosystem influences the structural change of systemic financial risk. Each level of risk in the systemic financial risk contains a large number of elements, which in turn make up the elements of the previous level of risk. Each level's elements are autonomous individuals who will have a diverse impact on the systemic financial risk associated with the activities. As a result, the systematic financial risk evaluation model in this paper is built using Vensim software and is based on the idea of a system dynamics model.

2. Related Work

Because systemic financial risk has such a large impact on a country's financial security and even global financial stability, it has piqued academic interest. Systemic financial risk, for example, is defined as the risk that the entire financial system will collapse or cease to function. This intuitive definition, on the other hand, is very unfavorable for measuring and analyzing systemic risk, particularly for the development of macroprudential supervision, which has drew scholars' attention. A comprehensive study on the measurement and early warning of systemic risk has been published in [15], but few scholars have looked at the overall study of systemic risk in China [16]. It was confirmed that there is a systemic risk spillover effect in listed commercial banks in China, especially during the crisis, by measuring the fluctuation of stock prices of 12 listed banks in China and constructing a quantile regression model. Literature [17, 18] further points out that there is a direct positive correlation between the size of banks and their risk contribution and negative externalities, and the magnitude and direction of risk spillover effects have an important influence on the stability of the financial system. Literature [19] holds that systemic financial risks will seriously damage the operational ability of the financial system, and it is difficult for the financial system to maintain stability. Its fragile characteristics will affect economic growth and social welfare and even threaten the whole financial system and macroeconomic stability. Literature [20] holds that systemic financial risk will lead to a wide range of financial service failures, resulting in partial or total losses of the financial system, and then the risk of serious impact on the real economy.

The structured method, which uses data from financial statements such as balance sheets of financial institutions to calculate the joint impact distribution of crises and then measures financial risks on that basis, is the most widely used of the major international financial risk measurement methods. Literature [21] uses quantile regression technology to calculate the systemic risk of the entire financial sector under the assumption of a single bank asset loss. According to [22], the financial stress index can measure the degree of potential risks faced by financial markets, making it the explained variable of the degree of systemic financial risks, while other leading indicators of financial risks are explained variables of systemic financial risks. Literature [23] assumes that systemic financial risk is a one-time occurrence. If Y is used to represent the crisis variable, it can only take the values 0 or 1, indicating that the crisis has not occurred or has occurred, respectively, and X is the above-mentioned crisis influencing factor. Literature [24] investigates past crisis events, identifies leading indicators of the crisis, and establishes a threshold for each indicator, which is determined using the "noise-signal ratio" method. The research method based on tail risk probability was used in [25]. It used the extreme value measurement method to estimate the tail risk of China's financial market and used it as the basis for measuring systemic risk. Literature [26] uses the RMB foreign exchange market pressure index to study the release process and effect of pressure, while [27] uses the vector autoregressive model of regional Markov matrix transfer to study the systemic risk of China's financial market and provides an early warning for future risks.

3. Research Method

3.1. Analysis of Influencing Factors of Systemic Financial Risk

3.1.1. Macroeconomic Operation Risk. A good macroeconomic environment is required for the effective operation of the financial markets. The financial market's effectiveness will be hampered as the macroeconomic operating environment deteriorates, resulting in unsustainable financial market stability and the emergence of systemic financial risks. The quality of a country's macroeconomic environment is influenced by the overall economic operation. The overall economic operation risk refers to the possibility that the economic operation deviates significantly from the equilibrium state. In practice, the degree of realization of macroeconomic development goals is often used to measure the overall economic operation risk. Therefore, the adjustment of industrial structure leads to the slowdown of economic growth, the difficulties of non-state-owned enterprises lead to the deterioration of employment environment, the internationalization of RMB aggravates the imbalance of international payments, and the inflation caused by high leverage will all have negative effects on the stability of financial order.

3.1.2. Financial Market Risk. On the one hand, financial market development can quickly and effectively guide the rational flow of funds and improve the efficiency of capital allocation; on the other hand, it has a pricing function, and financial market price fluctuation promotes financial innovation, increasing market volatility and bringing financial market risks while realizing risk dispersion and transfer. The stock market, credit bond market, and foreign exchange market are currently the most influential markets in China's financial market, and their risk characteristics are the most obvious. Although there has been no large-scale bond default in China's credit bond market in recent years, as the size of corporate credit bonds grows, the future debt repayment burden and pressure will grow, and the credit bond market's potential risks will intensify, posing systemic financial risks. The internationalization of the RMB, the opening of capital accounts, and the establishment of an offshore RMB market have brought the Chinese financial market and the international financial market closer together, and the risks of the international financial market have spread to the domestic financial market via a variety of channels. Therefore, financial market risk includes three dimensions: stock market risk, credit bond market risk, and foreign exchange market risk.

3.1.3. Financial Institution Risk. Financial institutions are an important part of the main body of financial ecology. Although financial innovation has given birth to diversified new financial institutions, at present, banks, securities, and insurance are still the most important financial institutions in China, and their risk levels and risk contagion among them play a vital role in the fluctuation of systemic financial risks. The risk contagion among financial institutions has contributed to the outbreak and spread of systemic financial risks. Therefore, financial institution risk is a collection of bank risk, securities risk, and insurance risk.

3.1.4. Risks of Nonfinancial Enterprises and Residents. The study of systemic financial risks should not be limited to financial institutions, financial market risks, or risk agglomeration and diffusion in the financial industry. To expand the research radius of systemic financial risks, we should pay close attention to all types of risk factors exposed in the development of nonfinancial enterprises and residents' consumption, as well as the transmission of risk factors to the financial industry.

3.2. Construction of Systematic Financial Risk Evaluation Index System. According to the definition and connotation of systemic financial risk, financial risk exists in different financial institutions or systems, so it is impossible to evaluate it by a simple method based on a single index data, but many factors must be considered. This paper selects the measurement index of systemic financial risk from four aspects: macroeconomic operation risk, financial market risk, financial institution risk, and financial enterprise and resident risk. The evaluation index is shown in Figure 1.

3.3. Construction of Systematic Financial Risk Evaluation Model Based on System Dynamics Model. The system dynamics model has obvious benefits when dealing with complex social system problems, particularly those that are nonlinear, are dynamic, and require low accuracy. The essence of the system dynamics model, from the standpoint of research thinking, is the concrete application of each theory in the research target field; from the standpoint of research, the system dynamics model is to bring various factors that affect the research objectives into the research framework and form a model for experiments.

3.3.1. Causality Diagram and Model Structure of Each Subsystem. To assess the systematic financial risk, we must first grasp its structure. Assume that the structural framework serves as the foundation for data classification and organization.

In this paper, the analysis of systemic financial risk is based on four primary risk indicators: macroeconomic operation risk, financial market risk, financial institution risk, and nonfinancial enterprise and resident risk. Therefore, this part is divided into four subsystems: macroeconomic risk subsystem, financial market risk subsystem, financial institution risk subsystem, and nonfinancial enterprise and resident risk subsystem to analyze the correlation among each subsystem (Figure 2).

3.3.2. Determination of All Levels of Weights of Systematic Financial Risk Evaluation Model from the Financial Perspective. Determining the reasonable index weight is very important to build a complete and scientific systematic financial risk evaluation model. At present, there are three main methods to determine the index weight:

(1) Subjective empowerment methods that are "function-driven" are highly dependent on experts' knowledge and experience, but the evaluation results can reflect the subjective preference of decision makers.
(2) The objective weighting method that is "difference-driven" determines weights by rigorous mathematical logic reasoning. Its main advantage is that it does not reflect the subjective color of decision makers but is based on the information characteristics of decision matrix.
(3) Integrated weighting method is present.

When comparing the first and second types of weighting methods, we can see that the objective weighting method relies on the system's mathematical and optimization theory, and it is extremely objective to deduce the weighting through rigorous mathematical deduction, but the weights obtained by this method are frequently contrary to the actual situation and difficult to explain, and this method is highly dependent on the selected model and data, and the weights obtained by different models are often quite different, lacking inheritance and order preservation. Although the outcome of the subjective weighting method is subjective and arbitrary, it is excellent in terms of explanation, inheritance, and maintaining order.

Therefore, this article also adopts the subjective and objective weighting method to ensure the reliability and authenticity of the weights: subjective weighting adopts the AHP (Analytic Hierarchy Process) method, and objective weighting chooses the CRITIC (Criteria Importance through Intercriteria Correlation) method.

Using AHP method, first of all, the relative importance of each factor to the target at the next higher level is assigned with 9-level Bipolar scale. For any target in the decision-making system, a judgment matrix is formed by pairwise

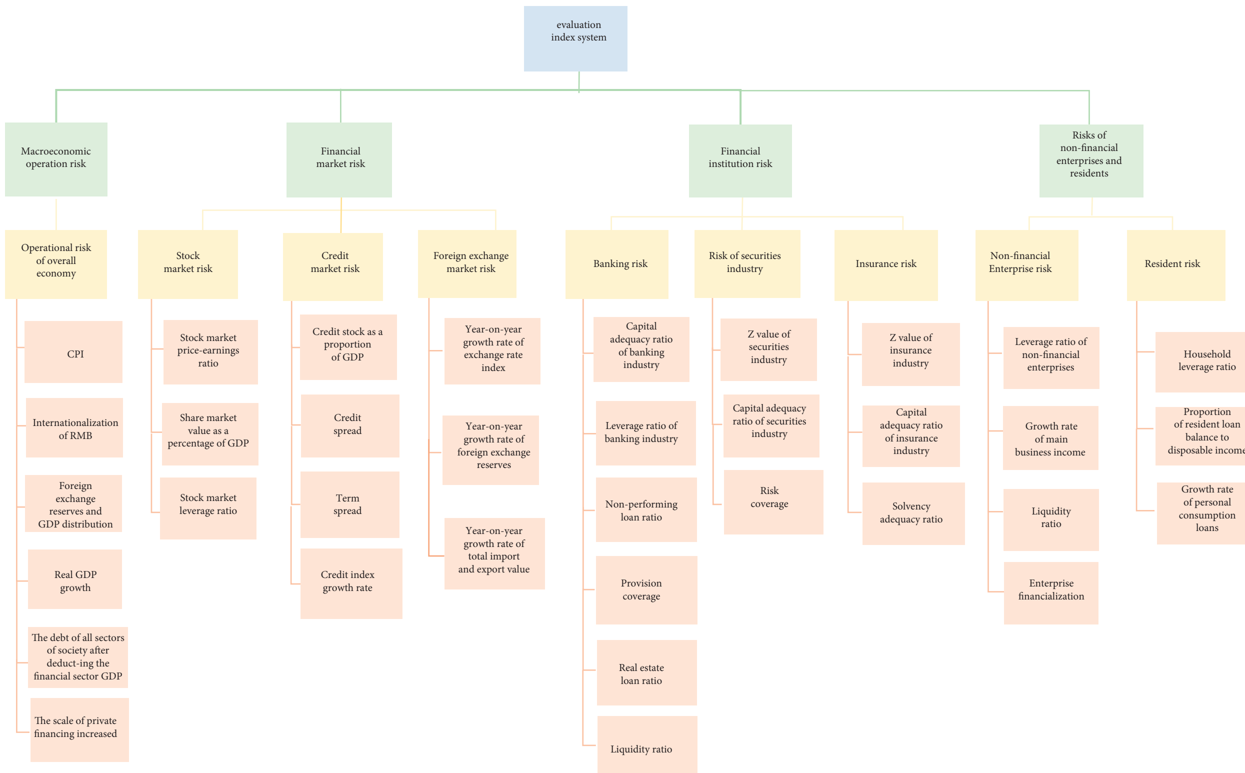

Figure 1: Systematic financial risk evaluation index system.

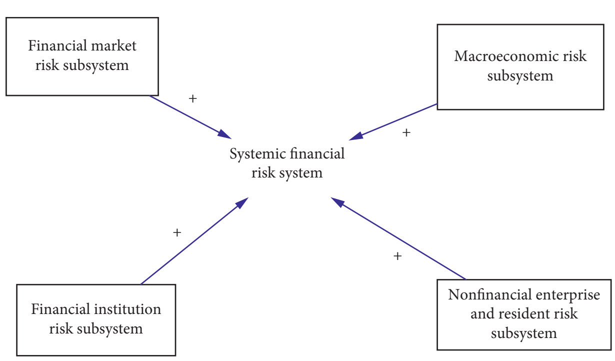

Figure 2: Structural diagram of systematic financial risk model.

judgment between the next level indicators. Take any first-level indicator A_i as an example, the corresponding number of second-level indicators is m, and b_{cd} is the importance ratio of the second-level indicators A_{ic} and A_{id} to A_i, then the judgment matrix expression is as follows, the importance meaning of b_{cd} value is as shown in Table 1, and $b_{cc} = b_{dd} = 1$.

$$c = (b_{cd})_{mm} = \left\{ \begin{array}{c} b_{11}\, b_{12} \ldots b_{1m} \\ b_{21}\, b_{22} \ldots b_{2m} \\ \ldots\ \ldots\ \ldots\ \ldots \\ b_{m1}\, b_{m1} \ldots b_{mm} \end{array} \right\}. \tag{1}$$

Secondly, the relative weight is calculated by the judgment matrix.

Step 1. calculate that product of elements in each row of the judgment matrix:

$$\mathrm{M}_c = \prod_{d=1}^{m} b_{cd} \quad c = 1, 2, \ldots, m. \tag{2}$$

Step 2. calculate the m-th root of M_c:

$$\omega_{ic} = \sqrt[m]{\mathrm{M}_c} \quad c = 1, 2, \ldots, m. \tag{3}$$

Step 3. carry out vector normalization on ω_{ic}:

$$\mathrm{W}_{ic} = \frac{\omega_{ic}}{\sum_{c=1}^{m} \omega_{ic}} \quad c = 1, 2, \ldots, m. \tag{4}$$

According to this method, $\mathrm{W}_{i1}, \mathrm{W}_{i2}, \mathrm{W}_{ic}, \ldots\ldots \mathrm{W}_{im}$ are the weight of each secondary index to its primary index A_i, and the subjective weight coefficient of each index is obtained by analogy.

In order to ensure the rationality and correctness of the obtained feature vector, consistency test should be carried

Table 1: Grade 9 Bipolar scale assignment table.

Scale	Meaning
1	c and d are equally important.
3	Compared with indicator d, indicator c is slightly more important.
5	Compared with indicator d, indicator c is more important.
7	Compared with indicator d, indicator c is particularly important.
9	Compared with indicator d, indicator c is extremely important.
2, 4, 6, 8	The intermediate value of the above adjacent judgment.
Reciprocal of the above scale	The importance ratio of c to d is b_{cd}, and then the importance ratio of d to c is $1/b_{cd}$.

out. When the test is passed, the feature vector can be used as the weight vector; otherwise, the judgment matrix should be reestablished or corrected.

Consistency test formula:

$$CR = \frac{CI}{RI}. \quad (5)$$

When $CR < 0.1$, it is considered that the consistency test of the judgment matrix has passed.

Among them,

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)}. \quad (6)$$

$\lambda_{\max}$ is the largest characteristic root; RI is a random consistency index, and the values are shown in Table 2.

Diakoulaki (1995) proposed the CRITIC method, which uses contrast strength and conflict between evaluation indexes to determine the objective weight of evaluation indexes. Standard deviation is used to measure the intensity of the contrast between indicators, while the correlation coefficient is used to describe the conflict. CRITIC-based weighting indicators frequently have two distinguishing features: first, data fluctuation has a significant impact on the weighting; and second, data are frequently related. To assign objective weights to indexes, this paper employs the CRITIC method.

G is defined as the amount of information in the systematic financial risk evaluation system. Then, for any first-level index A_i, the information content of the corresponding c-th second-level index A_{ic} is

$$g_{ic} = \sigma_{ic} \sum_{d=1}^{m} (1 - r_{cd}), \quad c = 1, 2, 3 \ldots\ldots m, \quad (7)$$

where σ_{ic} is the standard deviation of A_{ic} and r_{cd} is the correlation coefficient between A_{ic}, A_{id}, so $\sum_{d=1}^{m} (1 - r_{cd})$ can represent the conflict between indicators.

The larger the g_{ic}, the more information it contains, and the higher the corresponding weight. Therefore, the objective weight φ_{ic} of g_{ic} is calculated as follows:

$$\varphi_{ic} = \frac{g_{ic}}{\sum_{c=1}^{m} g_{ic}} \quad c = 1, 2, 3 \ldots\ldots m. \quad (8)$$

According to this method, the objective weight coefficients of indicators at all levels are obtained.

The measurement of systemic financial risk index is, in the final analysis, the measurement of risk index in four aspects: financial market, financial institutions, nonfinancial enterprises and residents, and overall economy. At the same time, the overall level of systemic financial risk can be obtained by synthesizing according to their respective weight proportions.

4. Results Analysis and Discussion

4.1. Determination of Data Source and Initial Value of Model. Part of the original data and information in this model comes from reputable public databases like the China Statistical Yearbook and wind, while the rest comes from official websites like the IMF and the People's Bank of China. Because the most recent China Statistical Yearbook is the 2020 Yearbook, with data up to 2019, the evaluation period for systemic financial risk in this paper is 10 years, from 2010 to 2019.

As the table function value, take the growth of each three-level index from 2010 to 2019. Before using the model for evaluation, dimensionless treatment of the data of three-level indicators should be performed in order to make the data more comparable. According to formula (8), indicators with a positive correlation with secondary targets are positively dimensionless, whereas indicators with a negative correlation with secondary targets are inversely dimensionless (9).

$$x' = \frac{x - \min(x)}{\max(x) - \min(x)},$$
$$x' = \frac{\max(x) - x}{\max(x) - \min(x)}. \quad (9)$$

Take the weight of each index as the ratio constant of the model. The index weights of all levels in the model are weighted by AHP method with subjective weighting and CRITIC method with objective weighting, respectively.

4.2. Model Test Result Analysis

4.2.1. Consistency Test Result. Consistency test is carried out on the judgment matrix of indicators at all levels of systemic financial risk, and the test results are shown in Table 3.

From Table 3, it can be seen that the judgment matrices of decision-making objectives at all levels of systemic financial risk have passed the consistency test. AHP is effective in empowering.

Table 2: Numerical value of random consistency index *RI*.

Order	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 3: Consistency test result.

Index	Judgment matrix order	Maximum characteristic root $\lambda_{\max}$	Consistency index *CI*	Average random consistency index *RI*	Consistency index *CR*	Have you passed the consistency check?
Financial market risk	3	3.006	0.003	0.58	0.005	Pass
Financial institution risk	3	3	0	0.58	0	Pass
Nonfinancial enterprises and residents' risk	2	2	0	0	0	Pass
Overall economic risk	6	6.289	0.058	1.24	0.047	Pass
Stock market risk	3	3	0	0.58	0	Pass
Foreign exchange market risk	3	3.018	0.009	0.58	0.015	Pass
Credit market risk	4	4.088	0.029	0.9	0.032	Pass
Banking risk	6	6.11	0.022	1.24	0.018	Pass
Insurance risk	3	3.009	0.005	0.58	0.009	Pass
Risk of securities industry	3	3	0	0.58	0	Pass
Nonfinancial enterprise risk	4	4.072	0.018	0.9	0.020	Pass
Resident risk	3	3.014	0.007	0.58	0.012	Pass

4.2.2. Model Operation Inspection. The Vensim software includes a model checking tool that checks the model for mechanical errors in equations, variables, and dimensional units. Nonstructural and logical surface errors, such as unit mismatch at both ends of the equation and negative stock variables, are referred to as mechanical errors. The system of financial risk equations from the perspective of financial ecology has passed the mechanical error test, and the model can run as a result of testing and adjustments.

4.2.3. Model Authenticity Test. Comparing historical data with model simulation data, if the error between them is less than 10%, the model simulation value is considered to be valid, which is also called historical test. In this paper, four common indicators such as CPI, the growth rate of social financing scale, the share of stock market value in GDP, and the rate of nonperforming loans in the banking industry are selected as the test variables, and the test time is from 2010 to 2019. The inspection results are shown in Figures 3–6. The error between the model simulation value and historical data is less than 4%. The model has passed the authenticity test, and the model simulation is effective.

4.3. Analysis of the Evaluation Results of Systemic Financial Risk. We can construct an evaluation index describing China's systematic financial risk after determining the weight of the systematic financial risk evaluation index. We must not only grasp the state of financial risks as a whole, but also analyze the state of financial risks in each submarket in order to objectively and comprehensively assess China's systemic financial risks.

Systemic financial risks, structurally speaking, are ubiquitous and exist in various markets within the system, thus encompassing all aspects of systemic risks, in which submarkets are interconnected and form systemic financial risks. Overall, systemic financial risk is an evolving process, and the state of each stage will change as well, providing a description of the previous state as well as a hint of future development trends. As a result, an objective assessment of the state of systemic financial risk is required. Figures 7–12 depict the change trend of the systemic financial risk index.

First and foremost, based on the overall trend, other submarkets, in addition to financial institutions, are becoming increasingly risky. The pressure levels of macroeconomic operation risk, financial market risk, and nonfinancial enterprise and resident risk are all relatively close, and the risk trend is from low to high. The risks of nonfinancial enterprises and residents, as well as macroeconomic operation risks, are relatively stable in the early stages of the samples chosen in this paper, but they all show a one-way increasing trend in the later stages.

Second, from the standpoint of internal structure, each subrisk market's indexes are interconnected and collectively reflect systemic financial risks. We can see that financial institution risks are closely related to China's asset economy and that banks' credit business has always had a significant impact on China's stock market and has become a significant source of systemic financial risks, by analyzing the financial risk measurement results of financial institution risks. The risk of financial institutions has been fluctuating, and speculation is extremely dangerous. International hot money, influenced by the external market, has a constant impact on the domestic

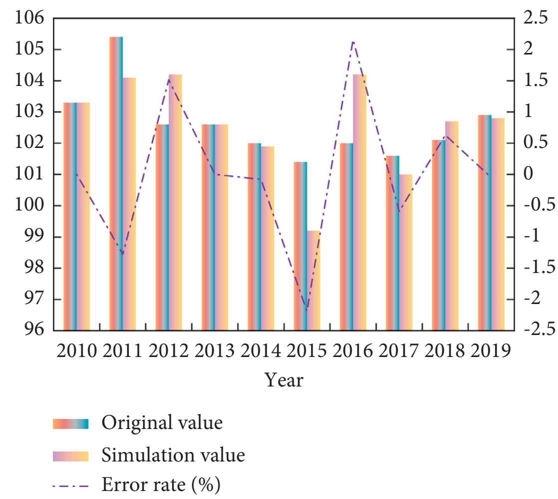

Figure 3: CPI authenticity test result.

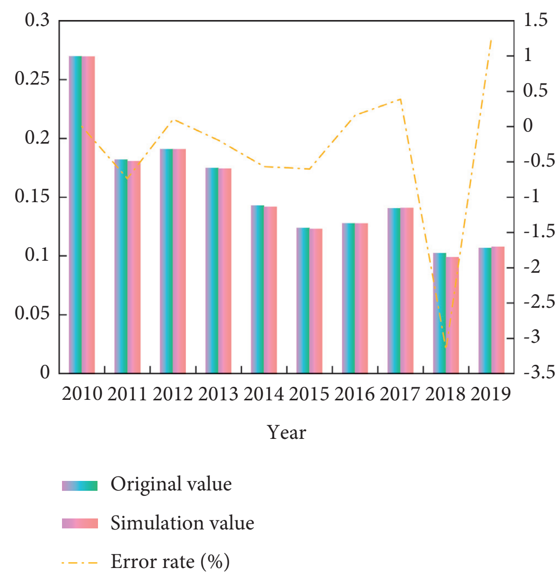

Figure 4: Truthfulness test results of social financing scale growth rate.

banking industry and stock market, and banks' rising financial risk drives the domestic stock market's rising financial pressure.

Then, from the perspective of fluctuation characteristics, there are significant differences in risk indices of each submarket. From 2010 to 2019, with the continuous promotion of interest rate marketization, the fierce competition among major banks increased the competition cost of small and medium-sized banks, and then the "money shortage" problem also highlighted the short-term liquidity problem faced by the banking system, which made the risk level of financial institutions improve in 2012. In terms of macroeconomic operational risk, the macroeconomic operational risk has increased to a certain extent. From these figures, it can be observed that the risk of nonfinancial enterprises and residents in China has been rising almost all the time from 2010 to 2019. On the whole, the financial risk fluctuation of financial institutions in China is not great.

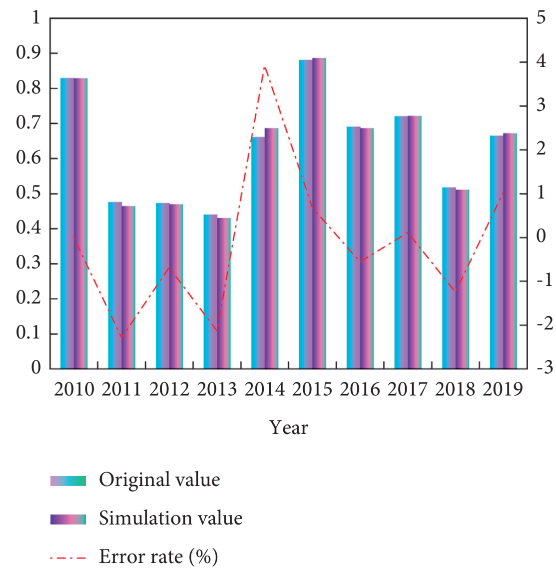

Figure 5: Authenticity test results of stock market value as a proportion of GDP.

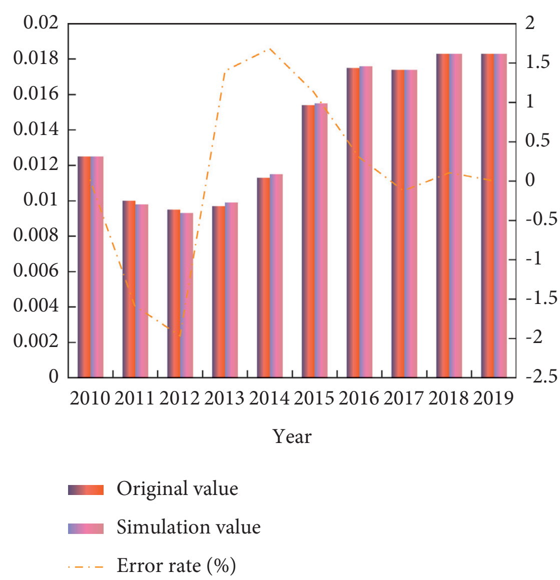

Figure 6: Truthfulness test results of nonperforming loan ratio in banking industry.

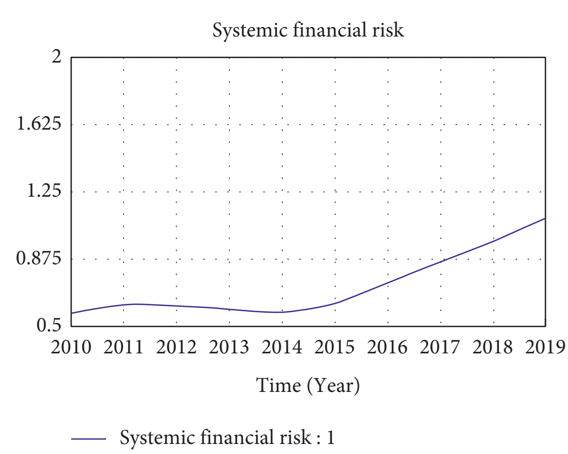

Figure 7: China's systemic financial risk level based on system dynamics model.

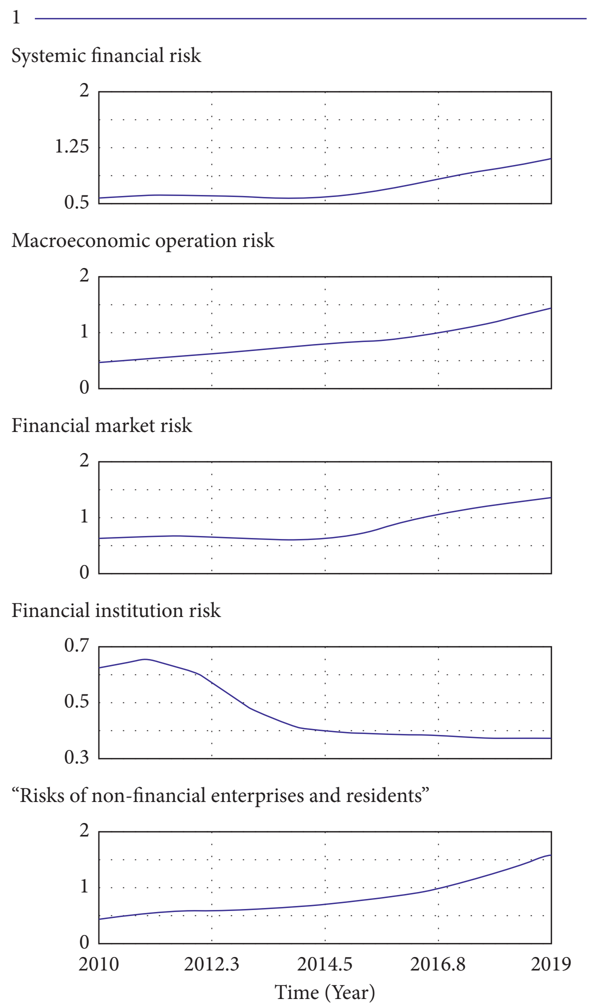

Figure 8: Comparison of systemic financial risk level and risk level of each subsystem.

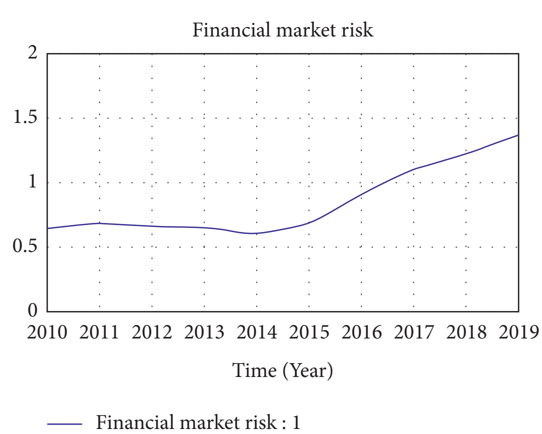

Figure 9: Financial market risk level from 2010 to 2019.

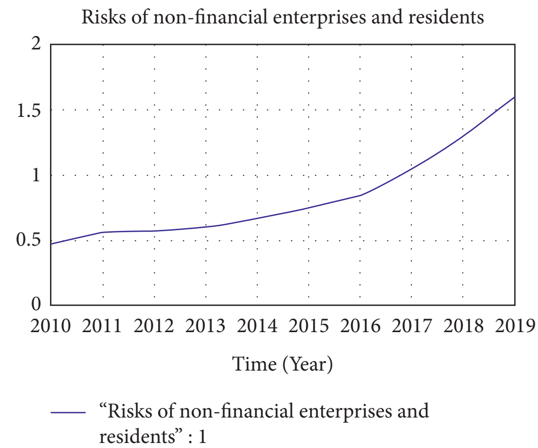

Figure 10: Nonfinancial enterprise and resident risk level from 2010 to 2019.

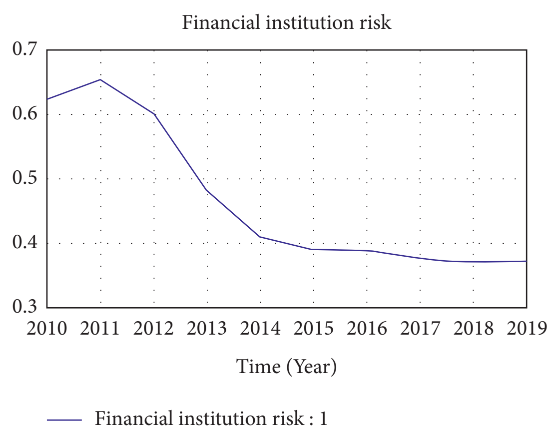

Figure 11: Financial institution risk level from 2010 to 2019.

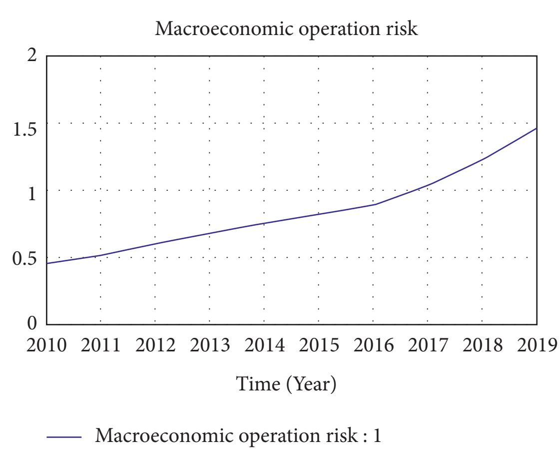

Figure 12: Macroeconomic operation risk level from 2010 to 2019.

5. Conclusions and Suggestions

5.1. Conclusion. This paper establishes China's systematic financial risk evaluation model, based on the system dynamics model, and selects four dimensions: financial market, financial institutions, nonfinancial enterprises and residents, and overall economy. As the foundation for the development of China's comprehensive financial risk index model AHP and CRITIC are chosen on this basis to determine the index weights of submarkets and the weights of each submarket, in order to synthesize and comprehensively reflect systemic financial risk and each market's risk index, which is used to describe its state. The following is the final conclusion:

(1) The level of systemic financial risk is always greater than 0, indicating that China's financial system as a whole is in a moderate financial risk state, as determined by the identification and analysis of China's systematic financial risk index.

(2) The systematic financial risk index from 2010 to 2019 is calculated using the CRITIC and AHP weighting methods. The findings show that financial institutions, financial markets, nonfinancial enterprises and residents, and macroeconomic operations, all play a role in China's financial risk index fluctuation. There are some systematic correlations, but there are also some differences between submarkets.

(3) There are significant differences in risk indices of each submarket in terms of fluctuation characteristics. The risk of macroeconomic operation increased to some extent between 2010 and 2019. In general, the financial risk fluctuation of Chinese financial institutions is not significant.

5.2. Policy Advice. Continue to encourage high-quality economic growth. Economic development of high quality is the only way to keep systemic financial risks at bay. We can only optimize the allocation of financial resources and resolve financial risks if we continue to promote high-quality economic growth.

Intensify the financial industry's "penetrating" supervision. "Penetrating" supervision is based on the principle that substance is more important than form, and it entails delving deeply into the true identity of financial market subjects behind financial activities, as well as identifying the transaction essence hidden beneath the formal cloak of complex financial products, in order to conduct targeted and deep supervision and adjustment of financial activities using effective supervision tools. "Penetrating" supervision can elucidate the logic of financial behavior, investigate the source of financial risks, and aid in the systematic prevention of financial harm.

Focus on nonfinancial enterprise risks, as well as preventing and controlling risks in resident departments. It is critical to limit the deviation from reality; reducing leverage is essential, and improving enterprise competitiveness is critical.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Analysis on the Penetration of Emotional Education in College Physical Education Based on Emotional Feature Clustering

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Physical education is a highly skilled education offered in colleges and universities. Teachers do not appear in front of inanimate machines as laborers, and they are not the same as gardeners who grow colorful trees, according to their essential characteristics. Their work is aimed at flesh-and-blood students who are sentimental, thoughtful, and engaged in critical thinking. As a result, schools should prioritize physical education and place a premium on emotional infiltration education, improve learning interest, improve teacher-student relationships, create a harmonious teaching environment, and improve teaching quality; it has a significant impact on an individual's entire life. The modern educational process places a premium on the transmission of rational knowledge while overlooking the accumulation of emotional experience. The cultivation and development of emotional feeling ability, emotional expression, and expression ability receive less attention than the training and improvement of language, concept, logic, and reasoning abilities. Emotion feature clustering is used to propose an emotion recognition method in this study. This method generates extended features for classification by constructing a co-occurrence matrix based on the co-occurrence relationship of emotion features and then by applying the spectral clustering method. The binary value of whether emotional features of emotional education in college physical education appear in a particular cluster is then expressed as a feature and extended to the original training feature set, alleviating the problem of sparse features.

1. Introduction

In contemporary universities, there will be such a situation, that is, students who are active in the playground will be stronger than those who lack physical exercise, which has to cause concern in schools. Physical education in colleges and universities is a highly skilled education. Its essential characteristics determine that teachers do not appear in front of inanimate machines as laborers and are different from gardeners who cultivate colorful trees. Their work targets young students who are full of flesh and blood, sentient, thoughtful, and active in thinking. This determines that schools should play a leading role in physical education and attach importance to and implement emotional infiltration education [1]. According to modern psychology theory, the factors that affect students' learning include not only their intelligence factors but also non-intelligence factors such as emotion and will. This non-intelligence factor can lay a good psychological foundation for a person's socialization and meet his psychological needs [2]. In the past, physical education in colleges and universities mainly focused on competitive minority sports, but now our requirements should develop into popular sports of art and ecological sports so that sports can become a necessity for people to survive. Therefore, in college physical education, physical education teachers should add emotional education instead of simply teaching physical education [3], improve interest in learning, harmonize the relationship between teachers and students, form a harmonious teaching atmosphere, and improve teaching quality, which even has an important influence on his whole life. The modern educational process emphasizes the imparting of rational knowledge and neglects the accumulation of emotional experience. Emphasis is placed on the training and improvement of language, concept, logic, and reasoning ability but less on the training and development of emotional feeling ability, emotional expression, and expression ability [4, 5]. This educational model ignores people's emotional characteristics, cannot meet people's different emotional needs, cannot stimulate and regulate people's emotional mechanism, and cannot say it has a profound impact on people's emotional aspects.

The method of emotion recognition proposed in this study is based on emotion feature clustering. This method generates extended features for classification by constructing a co-occurrence matrix based on the co-occurrence relationship of emotion features and then by using the spectral clustering method. Because the training dataset for the learning method of emotional feature clustering is small, there may be an emotional education situation in college physical education where the features in the test dataset do not appear in the training dataset, resulting in unsatisfactory classification results [6, 7]. To put it another way, the sparsity of this feature distribution has an impact on emotion classification accuracy. To complete the final emotion classification, the two classifiers collaborate. The method proposed in this study is based on the following basic assumption: in college physical education with similar emotional tendencies, emotional words of emotional education have a high probability of appearance in consumer comments with similar emotional tendencies; these "similar" emotional features can then be clustered based on their co-occurrence relationship in comments [8, 9]. The goal of image retrieval based on emotional semantics is to investigate the emotional analysis of emotional education features in college physical education, to describe and extract these features in a way that is appropriate for people's psychological reactions to the features, and to cluster the emotional features [10].

The emotion recognition algorithm based on emotion feature clustering is based on an observation: words or phrases of emotional education in college physical education with the same emotional tendency are more likely to appear in the same product comments [11, 12]. For example, in general, the probability of "very good" and "perfect" appearing in the same comment with a favorable emotional tendency is higher than that of "very poor" and "perfect" appearing in a comment together [13]. By using the emotional characteristics of emotional education in college physical education with unlabeled emotional category data to cluster the emotional characteristics, the number of available clusters is limited [14]. Then, at this time, the binary value of whether the emotional features of emotional education in college physical education appear in a certain cluster is expressed as a feature and extended to the original training feature set, which can alleviate the problem of sparse features. Emotion recognition algorithm does not depend on the specific mathematical description, has good global complex combination optimization ability, and has penetrated into many fields, such as coloring problem, vehicle route planning problem, and so on [15].

2. Related Work

Literature [16] puts forward that in college physical education, emotional educators enthusiastically carry out educational activities, induce and stimulate the positive emotion and positive attitude of the educatees in the process of education, make them in the best state of psychology, and regard the emotional cultivation of the educatees as one of the objectives of education. In literature [17] through the big data analysis method, in college physical education teaching, if physical education teachers can grasp students' inner feelings and use their own cultivation to adjust students' psychological trends and inner needs, they will shorten the psychological distance with students, produce a good classroom atmosphere, and achieve the desired teaching effect. Literature [18] shows that in order to implement emotional education in college physical education, teachers are required to invest in teaching with positive and full enthusiasm and good personal image; second, we should be good at using various methods and means to induce, motivate, and coordinate students' emotions. Literature [19] proposed that foreign research on text emotion recognition began in the 1990s. In text emotion analysis, researchers found two very interesting phenomena: first, emotional words with opposite tendencies generally do not appear together; second, emotional words with the same tendency often appear at the same time. In literature [20] through the big data analysis method, the professional norms of physical education teachers are highly intuitive, and their words, deeds, and emotions are very easy to have an impact on students. Literature [21] shows that the biggest feature of physical education teaching is to pay attention to physical activities. Physical education teachers' treatment methods and means of various classroom behaviors reflect their own educational wit and professional cultivation. Literature [22] puts forward that the semantic inclination of each sentence in the text can be obtained by weight first calculation method, emotional education is discussed on the combination of emotional words in college physical education, and the concept of the headword is put forward to calculate the inclination of words, which lays a foundation for more complicated emotional analysis of the text. In literature [23] through the big data analysis method, physical education teachers in colleges and universities should make full use of the advantages of disciplines in emotional education, pay attention to active and healthy emotional communication with students, win the respect and cooperation of students, and obtain the best educational effect. Literature [24] shows that the grades of praise and disapproval in college physical education can be divided into three categories (positive emotion, negative emotion, and neutral emotion) by star rating index, and the polarity classification of emotional education in comment text is completed by using the experimental algorithm using three classification methods, among which the method of the support-vector machine gets higher accuracy. Literature [25] puts forward a method of semantic correlation field based on two semantic tendencies of emotional word dictionary as the calculation basis of emotion classification.

Emotional education in college physical education is investigated in this study. Based on an emotional feature clustering algorithm, words or phrases with similar emotional connotations are more likely to appear in the same product review. In general, the likelihood of "very good" and "perfect" appearing in the same comment with a commendatory emotional tendency is higher than the likelihood of "very poor" and "perfect" appearing in the same comment with a disparaging emotional tendency. This study believes that if we can cluster these emotional characteristics based on their co-occurrence relationship, it will be beneficial to emotional education in college physical education.

3. Emotion Recognition Algorithm and Model Based on Emotion Feature Clustering

The emotion recognition algorithm of emotion feature clustering needs to label the data manually, which may require a lot of manpower and time. This is the most difficult and challenging work in the emotion recognition algorithm system. This study uses emotion feature clustering college physical education as the research object and considers the influence of different weights of interested and non-interested regions of emotional education on feature extraction. However, how to make users interactively select eigenvalues and set the weight of eigenvalues is a problem worthy of discussion. The emotion classification method of emotion recognition algorithm based on emotion feature clustering only needs to manually label a small amount of training data and then uses a large number of data without labeling the categories of emotion to train the learner, so as to classify consumer comments of unknown categories of emotion. This study selects 600 pictures in emotional education in college physical education as the original dataset, that is, the research object. The emotion analysis steps of analyzing emotion feature clustering are shown in Figure 1.

There is only a small amount of training data in the training dataset of emotion analysis of emotion recognition algorithm, so it may happen that the features in the test dataset do not appear in the training dataset, which may lead to unsatisfactory classification results. That is to say, the sparsity of feature distribution will affect the accuracy of emotion analysis. Emotional feature clustering based on the partition is the most widely used clustering. Its purpose is to divide the dataset into several subsets, that is, given a dataset with n tuples or records, k groups are constructed, and each group represents a cluster (for a given k, we can give an initial grouping method and then change the grouping through repeated iterations, so that the grouping scheme after each improvement is better than the previous one). This study describes the basic block diagram of the emotion recognition algorithm with divided emotion features, in which there are various methods in the first three steps, and different emotion recognition algorithms with divided emotion features can be obtained through combination, as shown in Figure 2.

The partition method is to divide n objects in set u into a given K subset so that the object similarity in the same set is high, while the object similarity in different sets is low. The definition of similarity is the key to division. Generally, it defines the objective function in the form of a formula and uses the heuristic method to minimize the value of the objective function.

$$J = \frac{1}{N} \sum_{K=1}^{K} \sum_{n=1}^{N} u_{nk} d^2 \left(\bar{x}_k - x_n\right), \tag{1}$$

where j is the sum of the mean square deviations of all objects in the set U and the corresponding cluster centers, xn is a data object in the space representing the objects, and x_k is the mean value of the cluster C_k. The formula of clustering standard aims to make the obtained clusters have the following characteristics: each cluster itself is as compact as possible, and each cluster is separated as much as possible.

The basic idea of emotion analysis based on emotion feature clustering and emotion recognition algorithm is briefly introduced: data are regarded as emotion analysis with different attributes, and the cluster center is the "emotion source" that emotion analysis is looking for, so the data clustering process can be regarded as the process of emotion analysis looking for emotion. It is assumed that the data object is $x = \{\text{xi} \mid \text{xi} = (\text{xi1, xi2, ..., xim}), I = 1,2,3, \ldots, n\}$. First, the algorithm is initialized. The pheromone $\tau(\text{O}) = 0$ of each path is set to O, and the parameters such as cluster radius R, statistical error ε, and representative object M are set. The weighted Euclidean distance dij between objects Xi and Xj is calculated, and the pheromones on each route are calculated as follows:

$$\tau_{ij}(t) = \left\{ \begin{pmatrix} 1, d_{ij} \leq r \\ 0, d_{ij} > r \end{pmatrix} \right. . \tag{2}$$

The probability formula for merging objects Xi into XJ is as follows:

$$P_{ij} = \frac{\tau^a ij(t) \eta^\beta ij(t)}{\sum_{s \subset S} \tau^a sj(t) \eta^\beta ij(t)}, \tag{3}$$

where $S = \{x_s | d_{sj} \leq R,\ s = 1,\ 2,\ \ldots,\ J,\ j+1, \ldots,\ n\}$. If PIJ (T) is greater than the threshold P_0, X_i is merged into the domain of X_J. Among the above clustering methods, the representative object m has a great impact on the operation efficiency and clustering results, and there are many selection methods of representative objects. Different methods can be tried according to the situation to avoid the algorithm falling into local optimization. Although the number of clusters does not need to be given in advance, the scale of clustering is limited because the cluster radius is preset.

The cluster centers of these two clusters are calculated according to the following formula, where n_1 is the number of samples in cluster A1 and n2 is the number of samples in cluster A2.

$$\bar{A} = \frac{1}{n_1} \sum_{k=1}^{n_1} X_k \left(X_k \in A_i\right) (i = 1, 2). \tag{4}$$

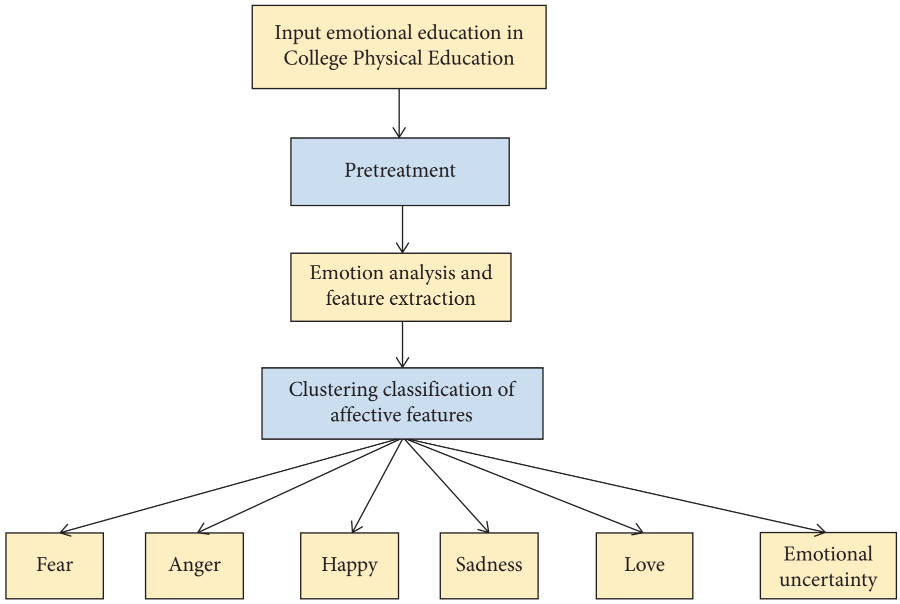

Figure 1: Flowchart of emotion feature clustering emotion recognition algorithm.

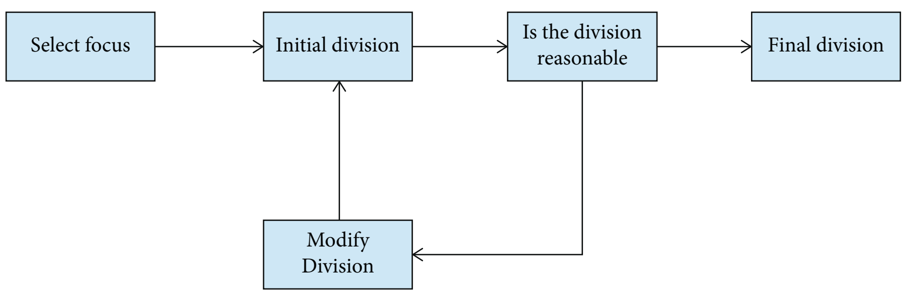

Figure 2: Framework of emotion recognition algorithm for emotion feature clustering.

After clustering, the distance between any two adjacent classes is calculated according to the clustering center of each class. If the distance between classes is less than the threshold value ε, the two categories are merged and the cluster center is updated at the same time. The distance between two classes is defined as the distance between the nearest two samples X and Y in two classes s and V.

$$d(S, V) = \min(d(x, y), x \in S, y \in V). \tag{5}$$

If we use emotion feature clustering in unlabeled emotion category data to cluster emotion features, the number of available clusters of emotion recognition algorithms is limited. The presence of an emotion feature cluster in the cluster of an emotion recognition algorithm is then expressed as a feature and extended to the original training feature set, alleviating the problem of feature sparseness.

Emotional feature clustering is a model that considers the probability relationship between physical and emotional education before and after college. It depicts the text's word sequence relationship. As a result, it is widely used in a variety of emotional recognition problems, including text word segmentation, automatic input, part of speech tagging, machine translation, and so on. In simple terms, the emotion feature clustering emotion recognition algorithm model counts the likelihood of a sentence or word sequence.

$$P(W_1, W_2, \ldots W_K), \tag{6}$$

where W represents each word, and k represents the length of the word sequence. We borrow the knowledge of the conditional probability of probability theory.

$$P(W_1, W_2, \ldots, W_K) = P(W_1)P(W_2|W_1)\ldots P(W_K|W_1, W_2, \ldots, W_{K-1}). \tag{7}$$

But if the length of k is too long, the word sequence modeling needs a very complicated model. Therefore, in engineering implementation, an approximation is often needed. Common methods include the n-gram model, maximum entropy model, conditional random field model, neural network model, and so on.

Affective feature clustering is one of the most used statistical affective feature clustering affective recognition algorithm models. The n-gram model is also known as the n-1-order Markov model. It is based on Markov's conditional hypothesis, that is, the probability of the current word is only related to the probability of the previous n-1 word.

$$P(W_K|W_1, W_2, \ldots, W_{K-1}) \approx P(W_K|W_{K-N+1}, \ldots, W_{K-1}). \tag{8}$$

Therefore, the probability of word sequence is approximately

$$P(W_1, W_2, \ldots, W_K) \approx \prod_{l=1}^{K} P(W_1|W_{l-n+1}, \ldots, W_{l-1}). \tag{9}$$

When the value of n is 1, 2, and 3, the corresponding emotion feature clustering emotion recognition algorithm models are called unigram, bigram, and trigram models, respectively. With the increase in grammar order, the model is more complex, so it is necessary to select the appropriate order in a specific application. The parameter estimation of the n-gram model generally uses maximum likelihood estimation (MLE).

$$P(W_l|W_{L-N+1}, \ldots, W_{l-1}) = \frac{\mathrm{Cont}(W_{l-n+1}, \ldots, W_1)}{\mathrm{Count}(W_{L-n+1}, \ldots, W_{l-1})}. \tag{10}$$

4. Application of Emotional Education in College Physical Education Based on Characteristic Clustering to Development

4.1. Emotional Education in College Physical Education Based on Emotional Feature Clustering. The emotion recognition algorithm of feature clustering is the sensory experience and reaction of people to emotional education in college physical education and the psychological stress state caused by the stimulation of external things to people's brains. Generally speaking, emotions include positive and negative, and each of them may contain rich content. In many cases, they are connected, and the community is now in people's reactions to external things. Physical education teachers and students are two sources of emotional analysis in physical education teaching. The greatest feature of physical education is to attach importance to physical activities, and the ways and means of dealing with various classroom behaviors by physical education teachers reflect their own educational wit and professional accomplishment. In the process of physical education, infiltrating the necessary emotional education can help college students learn respect, tolerance, friendliness, and self-confidence, cultivate collectivism and perseverance, and contribute to the formation of college students' good personalities. Any sport can show the strength, speed, dexterity, and vitality of human body and show the beauty of form and soul. Infiltration of emotion recognition education in physical education can help college students understand and appreciate this beauty, broaden their aesthetic vision, and promote their esthetic pursuit, thus forming a good esthetic taste. The emotion recognition algorithm of feature clustering is applied to emotional education in physical education in colleges and universities. Combined with the research results of modern educational information technology, volleyball teaching theory and methods and other aspects of emotion recognition algorithm, theoretical analysis, and experimental research are carried out in order to solve the one-sidedness of conventional teaching to cultivate students and further explore the influence of this emotion analysis on students' learning interest and academic achievement. Physical education teaching in colleges and universities is mostly in a relaxed environment, and many routine sports events are included in the teaching content, which broadens the vision of college students' sports knowledge, enriches their spare-time activities, and is conducive to stimulating and cultivating college students' emotional analysis of novelty, happiness, and satisfaction.

Physical education teaching characteristics determine that college students can gain a wide range of emotional analysis experience. For example, students will feel satisfied and happy after learning and mastering the fundamentals of sports movements; tension will arise during sports tests and competitive competitions; if you pass the test without difficulty or achieve good results in the competition, you will feel happy; and so on. Physical education teachers' professional norms are highly intuitive, and their words, actions, and emotions have a significant impact on their students. Individuals and classes receive physical education together in the process of physical education in colleges and universities, and physical activities necessitate competition. They often require mutual encouragement and assistance when competing as a team. They must learn to observe, unite, and love one another. It is simple to improve college students' collective reputation and friendship among peers, which is conducive to the development of a harmonious teacher-student and classmate relationship. The sports psychology, sports skills, and acceptance ability of students in college physical education differ. As educators, they should treat each student with respect and understanding, set different goals for them, use different methods and means to promote their progress, and encourage them to build confidence. As a result, physical education teachers should make full use of the subject's advantages in emotional education, pay special attention to positive and healthy emotional analysis, communication, and communication with students, earn students' respect and cooperation, and achieve the best educational effect possible. "Rational education" is the polar opposite of emotional learning.

This kind of education does not include emotional analysis into the feasible means of education. The emotional identification algorithm in emotional feature clustering regards the goal of knowledge imparting as the central position of emotional education, which is manifested in the indifference, distortion, and obstruction of students' emotional needs in the process of emotional education, the lack of normal emotional analysis and communication between teachers and students, the lack of vitality in emotional education activities, the inflexible form of emotional education, and the lack of initiative and interest of students. In the practice of physical education teaching in colleges and universities, college students need to bear certain sports load and overcome different degrees of difficulties. In this

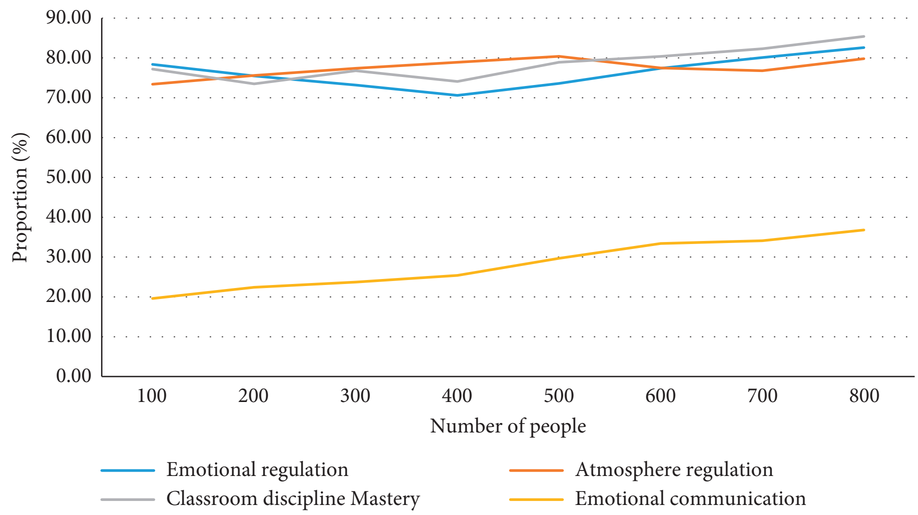

Figure 3: Proportion chart of emotional communication in college physical education.

process, college students can realize their own values and get different degrees of satisfaction, which will effectively enhance students' collective sense of honor. In college physical education teaching, we should not only cultivate students' action skills but also organize practice methods and logical thinking ability. It is also necessary to train students to have good learning psychological quality, personality quality, and esthetic quality, which are all indispensable and important components in professional emotion teaching. However, in the traditional teaching quality, action technology occupies the absolute center, and the factors of ability training are not given due attention, which has caused various defects and set up many obstacles to the implementation of quality education. Students have all kinds of emotional analysis experiences in their studies. Teachers must go deep into them and communicate with them in order to implement teaching more accurately. This is the emotional communication function of emotional education in physical education. As an activity requiring collective participation, the physical education class's teaching nature determines that students need to help and cooperate with each other in the course of class. During training, students are both practitioners and protectors of classmates, which can effectively cultivate students' sense of responsibility and obligation. A person's emotional experience is closely related to his life attitude, mental state, work efficiency, and intellectual potential, and it is an important part of his intelligence, personality, and thinking development. Emotion clustering is the driving force of the emotion recognition algorithm to catalyze college students' cognitive understanding, promote their moral level, and motivate students to make progress.

4.2. Analysis of Experimental Results. Physical education teachers should make full use of the advantages of the subject in emotional education, pay attention to positive and healthy emotional analysis, communication, and communication with students, win students' respect and cooperation, and obtain the best educational effect. The author conducted a questionnaire survey on the classroom behavior and influence of PE teachers on 600 college students of 2019 and 2020 in a university and made a statistical analysis, as shown in Figure 3.

One of them is emotional communication. Nearly 80% of students think that teachers do not communicate with them emotionally, there is emotional distance between teachers and students, and students stay away from teachers, which directly affect the teaching effect. Students have all kinds of emotional experiences in their studies. Teachers must go deep into them and communicate with them in order to implement teaching more accurately. This is the emotional communication function of emotional education in physical education, as shown in Figures 4–6.

Figure 4 shows that after the experiment, the experimental and control classes' interest in physical education emotional education showed significant differences, indicating that incorporating emotional teaching theory into the professional course of physical education emotional education in colleges and universities can improve students' interest in physical education. The reason for this is that applying emotional analysis teaching theory to professional physical education courses in colleges and universities meets students' direct physical education needs and stimulates their desire for sports. Students' direct sports needs refer to a desire to learn about or participate in a sport because it interests them. Figure 5 shows that the experimental and control classes significantly improved their technical evaluation results after the experiment when compared to the control class, and the difference is significant. It demonstrates that using emotional education theory in physical education classes is more conducive to mastering technical skills and improving the teaching effect of emotional analysis in physical education classes than traditional classes.

As can be seen from the statistical results in Figure 6, there is no significant difference between the students in the experimental class and the control class after the experiment. This shows that emotional teaching and conventional teaching methods in volleyball major courses in colleges and

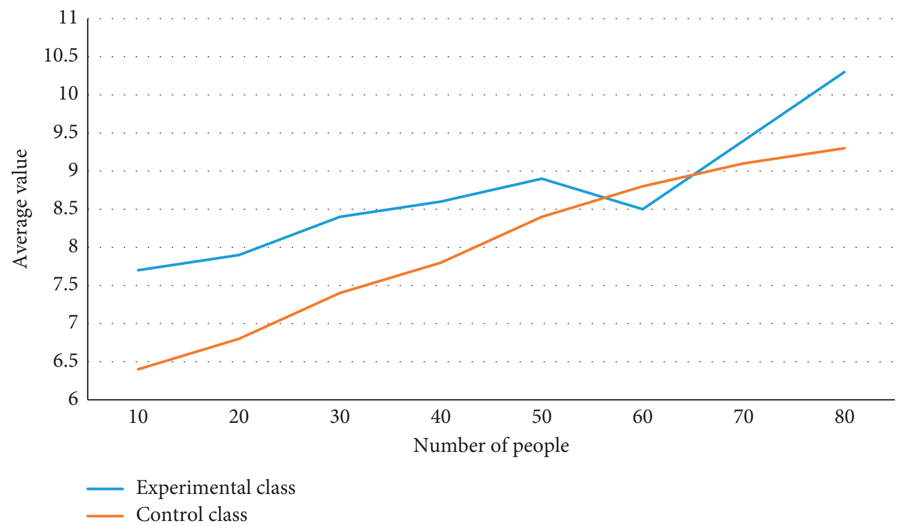

Figure 4: Comparison and analysis of comprehensive technical evaluation of emotional education technology in physical education (volleyball players).

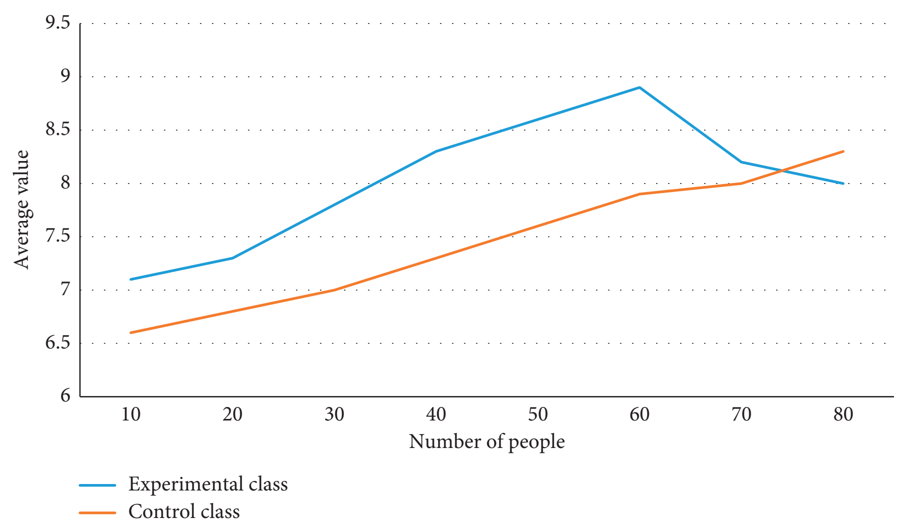

Figure 5: Comparison and analysis of comprehensive technical evaluation of emotional education technology in physical education (basketball players).

Figure 6: Comparison and analysis of comprehensive technical evaluation of emotional education technology in physical education (sprinters).

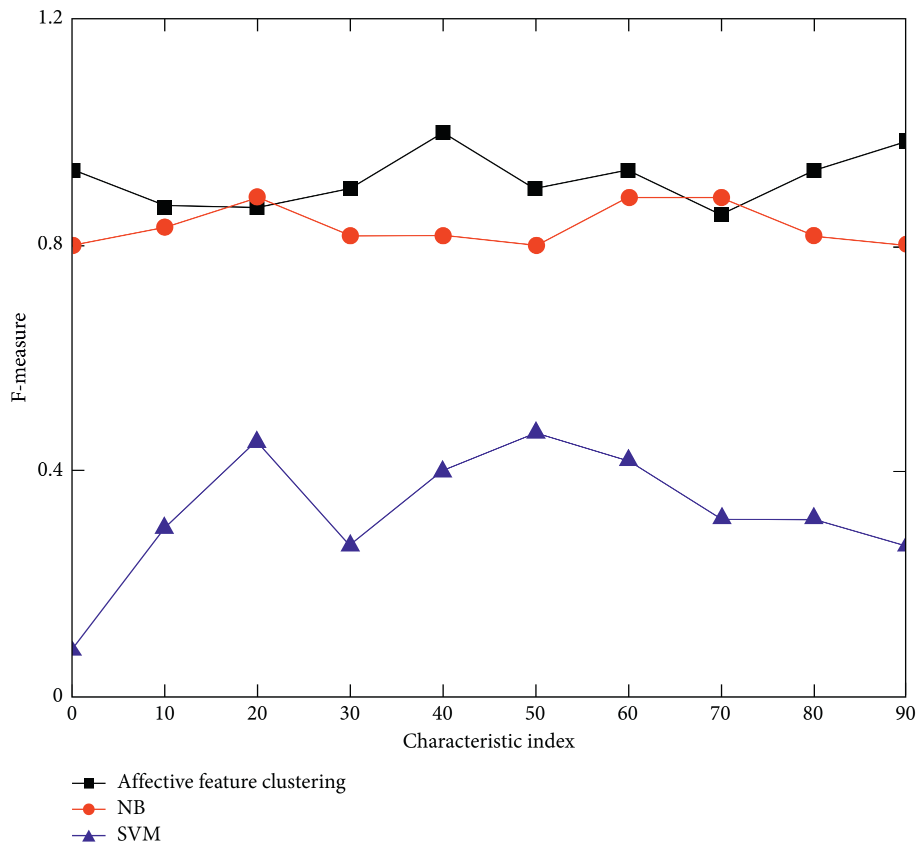

FIGURE 7: Recognition effect after emotional feature clustering (volleyball corpus).

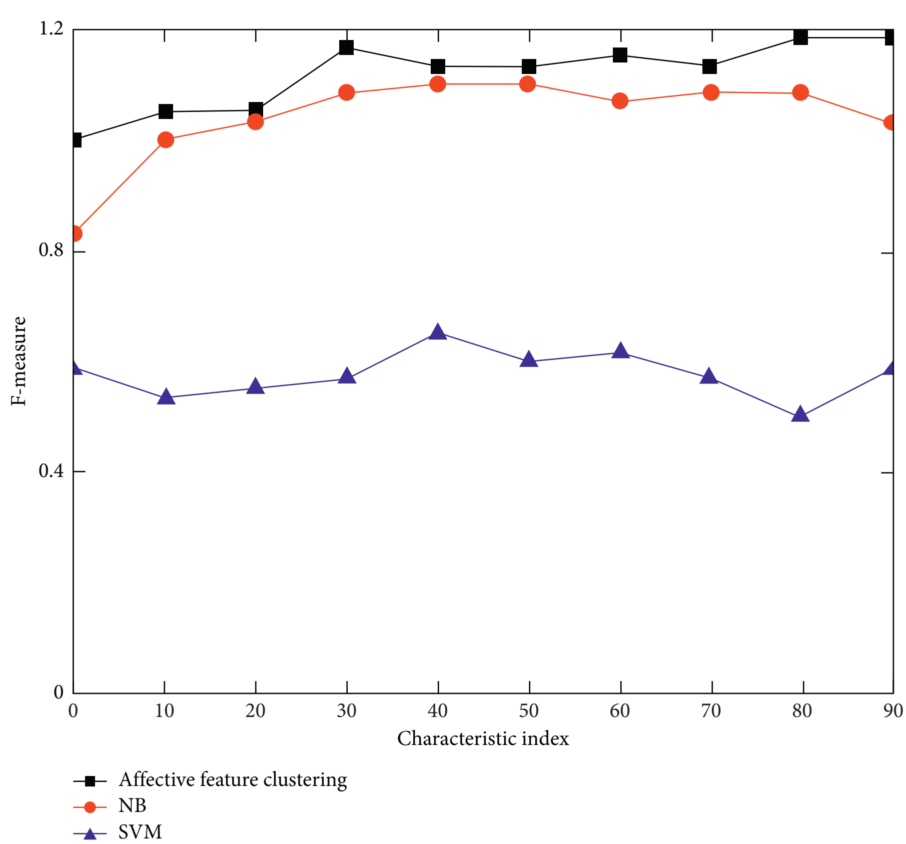

FIGURE 8: Recognition effect after emotional feature clustering (basketball corpus).

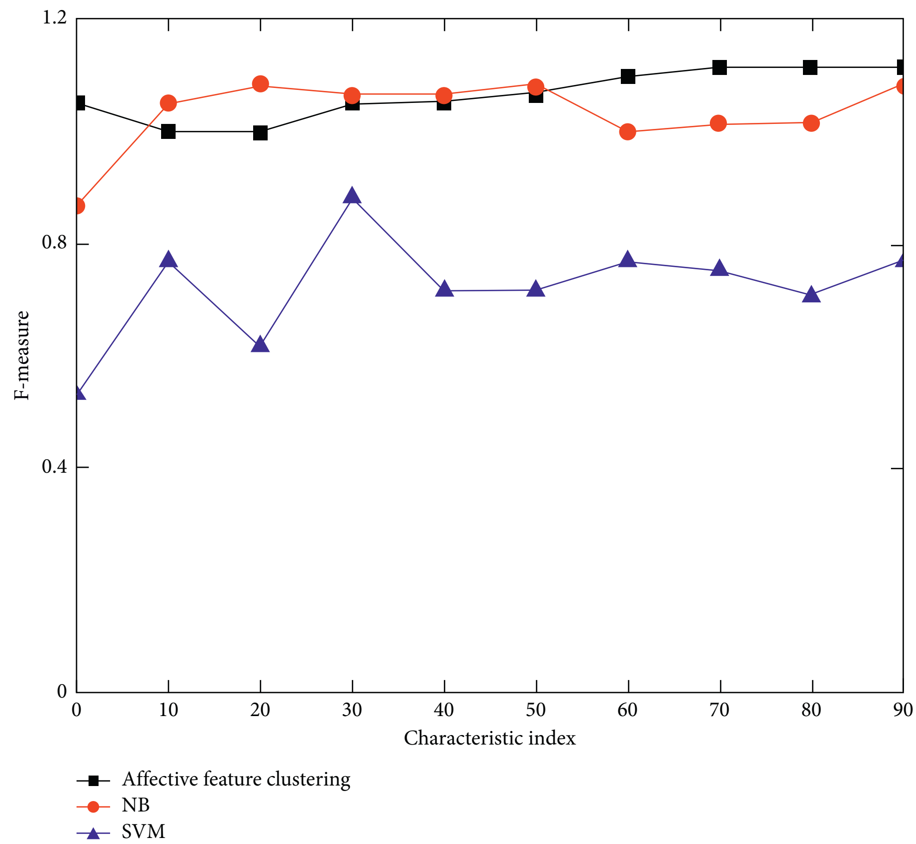

Figure 9: Recognition effect after emotional feature clustering (sprint corpus).

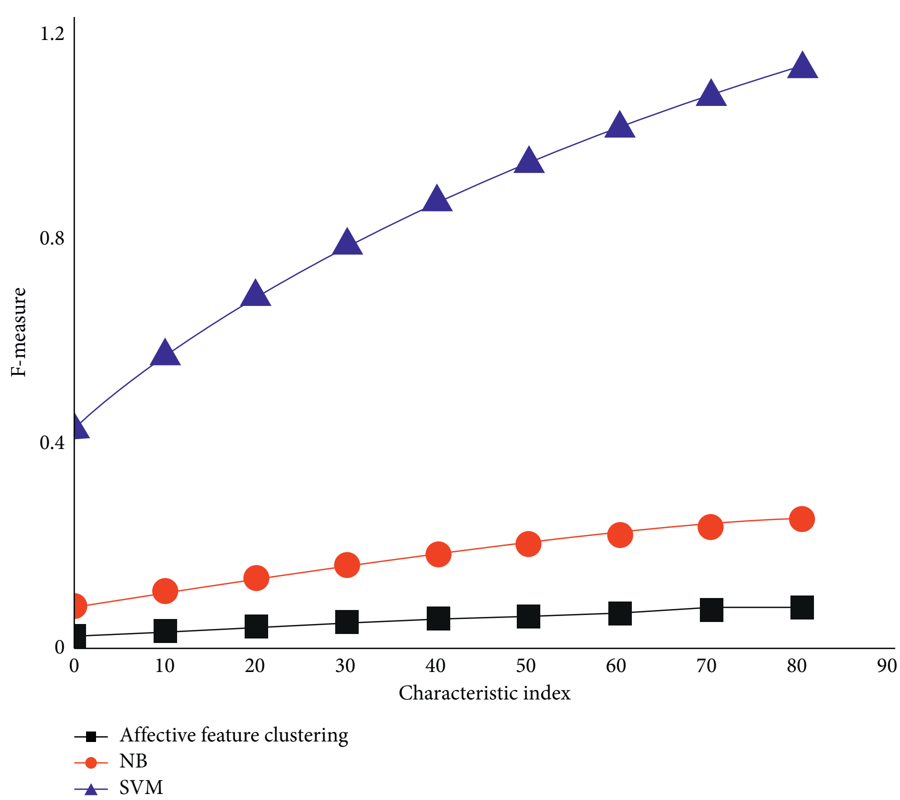

Figure 10: Recognition effect after emotional feature clustering (table tennis corpus).

universities have improved students' achievement to a certain extent. Compared with conventional teaching, emotional teaching does not significantly improve students' achievement in reaching the standard because the formation of motor skills is a long-term systematic and scientific learning and training process, and the level of students' achievement in reaching the standard is related to training time and training level. After we get the word vector, we use the similar characteristics of emotional feature clustering in emotional education in college physical education. We first use the emotional recognition method to divide all words into 500 categories, then use various labels to replace the corresponding words, and then classify the text emotional analysis. About 30% of the data are used as test data and the rest as training data. The classification results are shown in Figures 7–10.

Experimental results show that SVM still has a good classification performance. In the emotional education of physical education, the mixed feature classification of ternary grammar and TFIDF has the best effect. However, compared with the recognition rate in chapter 3, the overall recognition rate of text sentiment analysis using sentiment feature clustering results has declined. By analyzing the reasons, the biggest problem is that although Word2Vec quantifies the word direction and has good clustering characteristics, the use of clustering brings side effects of classification results: the fewer categories of emotional education in physical education in clustering will lead to the less accurate differentiation of features, for example, two words with far distance in the same category of emotional education in physical education may have more differences in meaning. Experiments have verified our conjecture, and our emotion recognition algorithm that expands the clustering category of emotional features will improve the success rate of emotional education in physical education. An extreme idea is that when each word is divided into a separate category, the classification results will be consistent with those in Section 3, that is, Word2Vec. Although the recognition rate of emotional education in physical education is not better, it also proves that the language model features and SVM classification method have higher recognition rates, and the network structure of emotional feature clustering also inspires us to use a neural network.

5. Conclusions

To summarize, physical education teaching characteristics determine that college students can gain a variety of emotional analysis experiences. For example, students will feel satisfied and happy after learning and mastering the fundamentals of sports movements; tension will arise during sports tests and competitive competitions; if you pass the test smoothly or achieve good results in the competition, you will feel happy; and so on. We focus on the implementation of formative evaluation in emotional teaching evaluation so that problems in the teaching process are brought to the attention of teachers and students right away, problems in teaching are remedied quickly, and students' learning errors are reduced. This study investigates emotional education in the context of college physical education. Based on emotional feature clustering, this study proposes improved methods for text features and classification algorithms using the original structure model. Before each clustering, the emotion recognition algorithm uses emotion feature clustering to calculate the two points with the smallest similarity as the starting cluster center. After clustering, the distance between each class is calculated, and the two classes with the shortest distance between them are combined. The goal of knowledge transfer is placed at the center of emotional education by the emotion recognition algorithm in emotion feature clustering. There is a dearth of standard emotion analysis and communication between teachers and students. Emotional education activities are devoid of vitality. Students lack initiative and interest as a result of the rigid nature of emotional education.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

A Novel Recognition Model of University Students' Psychological Crisis Based on DM

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The research on identifying college students' psychological crises can assist college administrators in better understanding of students' psychological changes and planning of intervention measures ahead of time to ensure college students' mental health. When confronted with unexpected events or major setbacks and difficulties, people experience psychological crises, which they can neither avoid nor solve using their own resources and stress methods. This paper proposes a method of college students' psychological crisis identification based on data mining technology to solve the problems that exist in the process of identifying psychological crises in college students and to improve the correct rate of identifying psychological crises in college students. In comparison to other technologies, data mining can uncover the link between students' psychological problems and their basic information, as well as the main causes of psychological problems, using statistical data.

1. Introduction

Psychological crisis refers to the serious psychological imbalance that individuals can neither avoid nor use their own resources and stress methods to solve when encountering unexpected events or major setbacks and difficulties [1]. Because of the differences in cultural background, family background, educational experience, individual development period, and personal experience, the situation of psychological crisis is not absolute. At the same time, each person's individual crisis varies with the change of time, place, event, and situation, and university students' psychological crisis identification has its own characteristics. When Hopfield fails to meet the objective function's requirements, the penalty function structure can be used to control the objective function of identifying psychological crises among university students, greatly reducing error rates and making network maintenance easier. As a result, current research is concentrating on the identification of university students' PCS. In the field of mental health education, incorporating big data technology into the identification of students' psychological crises, collecting and analyzing data from university students' daily lives at school, and improving the timeliness and accuracy of psychological crisis identification have become a new topic for psychological crisis identification workers in the information age. Every crisis has its particularity, and every crisis is unique and different [2, 3]. When we grasp and analyze the overall situation and start with the nature of the psychological crisis, we can still divide the crisis into three categories: first, developmental crisis, which is also called adaptive crisis or maturity crisis. It refers to the abnormal stress reaction caused by the sudden change of environment or self-physiology in the process of individual growth and development. Second, the situational crisis [4] refers to a situation in which individuals are unable to predict or control rare or unexpected extraordinary events. The key difference between a situational crisis and other crises is that the extraordinary events that trigger the crisis are unpredictable or difficult for university students to control, such as a parent's divorce, violent aggression, or strong interpersonal conflicts [5]. At this time, domestic research on PCS identification has been thoroughly examined from early warning to prevention to intervention, yielding some promising findings. However, most of the studies focus on the explicit crisis, such as what kind of external performance the PCS identification will have, with less attention paid to the implicit crisis [6].

In order to solve the problems existing in the process of university students' psychological crisis identification and improve the correct rate of university students' psychological crisis identification, this paper proposes a method of university students' psychological crisis identification based on DM technology. DM is a technology of data management, analysis, and processing, and a key step of knowledge discovery. The main applications of this method are correlation analysis, classification [7, 8], clustering, prediction time series model [9], and deviation analysis. However, the system designed by the system dynamics method is subjective in data classification, and the causal relationship is obscure and difficult to explain. The mental health analysis system designed by other weighted fuzzy logic theories [10] only stays at the data operation and management level such as data acquisition, statistics, query, and report, and the utilization efficiency of data is not high. The basic process of DM, a large number of DM, according to the definition of management, the preprocessed data get a reliable format, which is convenient for the mining wizard to process the data, and then enter the mining kernel to get the pattern set, which can express and explain the comprehensive knowledge base that users can understand and use after the pattern filtering of the mining manager.

The basic process of DM is as follows: a large number of raw data are extracted after data preprocessing according to the mining manager's data definition to obtain data in a correct and reliable format that is easy to process by the mining wizard, and then entered the mining kernel to obtain a pattern set that is expressed and explained, and then filtered by the mining manager to obtain a knowledge base that is easy for users to understand and generalize. They can organize the structure of a neural network according to the specific problems of university students' PCS identification, and they can effectively fit the changing characteristics of university students' PCS [11, 12]. Despite the fact that prevention, early warning, and intervention mechanisms for the psychological crisis have been established, extreme crisis events that appear to occur "for no apparent reason" continue to occur frequently. Because some crises are complex, difficult to identify, and difficult to detect, they can only have serious consequences if they are not addressed quickly and effectively [13, 14]. This paper examines the unique challenges of identifying psychological crises in university students and collects signals of psychological crisis detection in university students using specialized equipment [15].

2. Related Work

According to literature [16], university students' psychological crisis is universal, with complex symptoms and no quick fix, and it is the driving force for university students' growth and change, including the duality of danger and opportunity, as well as having time-specific characteristics. According to literature [17], using the big data analysis method and the ID decision tree algorithm, a data classification mining system model of university students' psychological problems was created. The system mined association rules using the Apriori algorithm. The main factors affecting psychological problems and their relationships were discovered through data testing. According to literature [18] and research, school, family, and societal losses have resulted from students' vicious wounding or self-injury incidents caused by the psychological crisis. As a result, establishing an effective early warning system for psychological crises among university students is essential for effectively preventing crisis events. According to literature [19], university students' psychological crises are characterized by unexpected events, relief from helplessness, pain, and potentially dangerous consequences. Literature [20] proposes a psychological classifier model based on artificial neural networks and fuzzy mathematics theory and uses training samples to build the model using the MATLAB neural network toolbox, resulting in more accurate classification results. According to literature [21], research shows that differences in the characteristics, forms, and stressors of university students' psychological crises categorize them into different types. The network structure of a mental health prediction system model based on the BP neural network algorithm was established using the artificial neural network toolbox in MATLAB, according to literature [22], in order to predict the mental health of university students. According to literature [23], through the method of big data analysis, the psychological crisis of university students is mainly attributed to four aspects: the crisis caused by physiological and psychological contradictions; crisis caused by interpersonal tension; psychological crisis caused by the market economy and employment pressure; crisis caused by sexual physiology maturity and sexual psychology imperfection. According to literature [24], research shows that the diagnosis experience of domestic and foreign psychologists is introduced into the expert system of mental disorder diagnosis through the expert system of the artificial neural network, so that the system can detect and diagnose students' mental health in all aspects, which provides convenience for improving the function of mental health education for university students. Literature [25] puts forward that the BP neural network algorithm is applied to university students' psychological disorder identification, and combined with "artificial intelligence" to establish a model, which can be used by university students to realize online self-diagnosis of psychological disorder categories, thus reducing the workload of some mental health managers and reducing the working pressure of college psychological counseling institutions.

Based on DM, this paper studies the identification of university students' PCS, and some achievements have been made in the application research of DM technology in psychological crisis prevention. The feasibility and effectiveness of DM technology in analyzing and predicting students' mental state, evaluating students' mental health, pattern recognition of psychological diagnosis, and early warning of psychological crisis have been proved. The application of DM in the classification technology model, psychological obstacle identification model, and psychological condition prediction network model of psychological crisis prevention has also achieved relevant research results.

3. Principle and Basic Steps of DM Technology

3.1. Principle and Algorithm of DM. DM is a process of extracting potential and useful information and knowledge from a large number of incomplete, fuzzy, noisy, and random data. The extracted knowledge is expressed as rules, concepts, laws, patterns, and so on. In the process of identifying university students' PCS, it is a crucial step to collect university students' PCS signals first. At present, sensors are mainly used to collect university students' PCS signals. The decomposition scale of wavelet transform is determined, and multiscale decomposed the original university students' PCS identification signal to separate the noise from the useful university students' PCS identification signal, which will correspond to different wavelet coefficients. Therefore, this paper uses laser sensors to collect students' PCS signals, which can reduce the cost of collecting PCS signals. The basic process of DM is as follows: a large number of raw data are extracted after data preprocessing according to the mining manager's data definition to obtain data in a correct and reliable format that is easy to process by the mining wizard and then the mining kernel is entered to obtain a pattern set that is expressed and explained and then filtered by the mining manager to obtain a knowledge base that is easy to understand and generalize. The DM model is shown in Figure 1.

DM is an instance-based inductive classification algorithm. For a given data set, this algorithm can create a decision tree model and extract intuitive and simple knowledge of classification rules. To begin, each of the classification measure data set's attribute values is classified and chooses the root node. Take, for example, a university's psychological management system. Some problems that are relatively unseen can only be revealed in a high-stress environment. There will be one-sided problems in the process of evaluating an individual's psychological state if we cannot realize dynamic data management and track and record the data of students at school. This traditional static data management method clearly lags behind students' psychological change processes, reducing the precision and timeliness of psychological crisis intervention. There are four modules in the current psychological management system: student/teacher service, psychological counselor module, parent module, and administrator module. To obtain the target DM set, raw data must be processed. Based on the above mining algorithms, the structure of the psychological crisis system based on three DM methods is shown in Figure 2.

Let the original university students' PCS signal.

$$y(n) = s(n) + n(n), \tag{1}$$

where $s(n)$ represents a useful signal of PCS of the university student.

Let $\psi(t) \in L2(R)$, whose Fourier transform is $\psi'(\omega)$, and the mother wavelet of wavelet transform is defined as

$$C_\psi = \frac{\int_R |\psi'(\omega)|^2}{|\omega| d\omega \ < \infty}. \tag{2}$$

$\psi\ (t)$ is expanded and translated to obtain

$$\psi_{a,b}(t) = \frac{1}{\sqrt{|a|\psi(t - b/a)}}. \tag{3}$$

The calculation formula of the wavelet coefficient is

$$\omega_{j,k} = \int_{-\infty}^{+\infty} y(n)\psi_{a,b}(n)\mathrm{d}t = \langle f, \psi_{a,b}\rangle. \tag{4}$$

The hard threshold method can be described as

$$T_h\left(\omega_{j,k}, \delta\right) = \begin{cases} \omega_{j,k}, & \left|\omega_{j,k}\right| \geq \delta \\ 0, & \left|\omega_{j,k}\right| < \delta \end{cases}. \tag{5}$$

The function $\varphi\ (xk)$ introduces to process the signal data xk of university students' psychological crisis so that it can meet the following conditions:

$$\sum_{k=1}^{N} \Phi\left(x_k\right) = 0. \tag{6}$$

The covariance matrix $c\ \varphi$ of the training data set of university students' PCS is calculated as follows:

$$C_\Phi = \frac{1}{N}\sum_{i=1}^{N} \Phi\left(x_i\right)\Phi^T\left(x_i\right), \tag{7}$$

and

$$\lambda_v = C_\Phi v. \tag{8}$$

3.2. Basic Steps of DM. The implementation steps of DM vary with different application environments, and there are differences for different problems and requirements. Each subtechnology of DM also has its own applicable characteristics and application steps. Complete steps of DM are as follows:

① Understand the data and data sources

② Obtain relevant knowledge and technology

③ Integrate and check data

④ Remove erroneous or inconsistent data

⑤ Establish models and assumptions

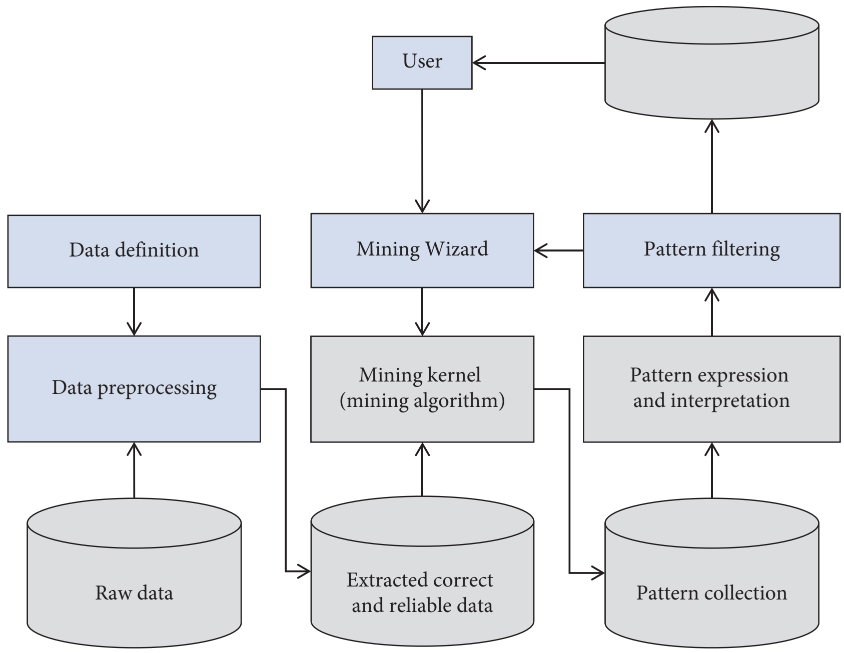

Figure 1: A model of DM.

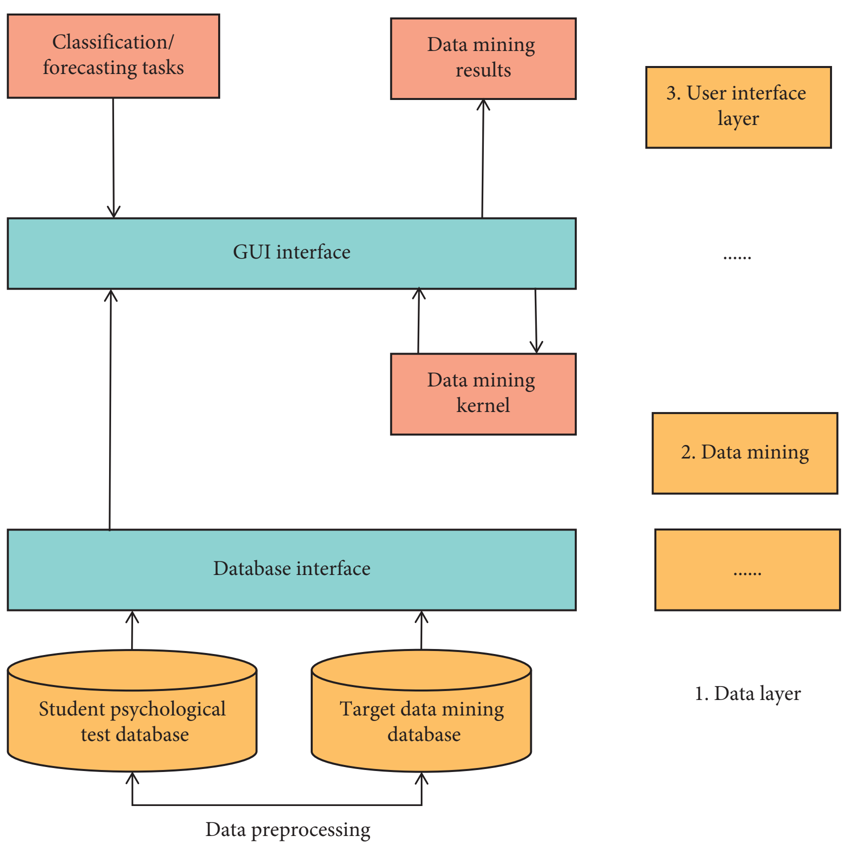

Figure 2: Structure diagram of the psychological crisis prevention system based on several DM algorithms.

⑥ Actual DM work
⑦ Test and verify the mining results
⑧ Interpretation and application

This paper examines the specific problems of identifying university students' psychological crises and collects the signals of identifying university students' psychological crises using specialized equipment. The wavelet transform's decomposition scale is determined, and then, multiscale decomposed the original university students' PCS identification signal to separate the noise from the useful university students' PCS identification signal, which will correspond to different wavelet coefficients. The performance of the identification model of university students' PCS is verified using test samples, and the identification results of university students' PCS are output. To summarize, Figure 3 depicts the process of identifying university students' PCS based on DM.

The single support vector machine (SVM) method for identifying university students' PCS directly extracts features from university students' PCS without denoising. This method is called SVM for short. The advantages of using neural network algorithm to optimize computer network connection are obvious. First, it effectively improves the connection efficiency of the computer network and makes the network run faster. Second, it effectively reduces the problem of increasing capital investment caused by optimizing computer network connection and maximizes the efficiency of capital utilization; that is, it can get the best optimization effect with the least capital. Traditional intervention did not fully tap the hidden value of student behavior data, which led to the related information being in a state of deep sleep. Only through big data mining and scientific utilization, and effective integration of unrelated and scattered data, can the accuracy of intervention be fully improved. After the analysis of big data students' psychological problems is completed, only by giving feedback to counselors and other psychological staff can the data value be further developed. Technologies such as economics, statistics, computer science, and applied mathematics are commonly used to make use of big data resources. However, psychological workers and managers rarely have such majors, which means that technical personnel are unsure how to intervene in a crisis, and psychological educators are unaware of big data technology's application methods. Students' psychological counseling, Internet access, and loan information, on the other hand, will be subject to privacy protection. More attention from the relevant personnel is required to determine whether this type of data is leaked or not, and whether it can be directly used, among other things.

4. Research and Implementation of University Students' PCS Identification

4.1. Identification of University Students' PCS Based on DM. The DM model based on the comprehensive CART decision tree, BP artificial neural network, and pattern recognition, which learn from each other's strengths, is embedded into the current school psychological management system to realize the psychological crisis prevention system. The complex averaging operation is transformed into functional regular operation, which greatly saves the calculation time of university students' PCS identification and realizes better interaction of network information data. Any behavior has a precursor. At present, students' psychological information processing ability is poor, and the sources are relatively few. Therefore, there is a lack of use-value, which leads to the lack of validity of the data held by counselors and affects their ability of judgment and analysis. Big data have the function of data mining, which can deeply mine and analyze massive data, and effectively predict the development law of things based on it, thus improving the prediction accuracy. Big data analysis can find the rules behind a large amount of data by studying students' external behavior and judge and predict students' behavior patterns and psychological state from all aspects of study and life. To integrate all kinds of data from various channels, it is necessary for the school work leading group to take the lead in establishing a data collection platform for psychological crisis intervention. The collection platform integrates and analyzes the data of various departments, timely provides valuable information for school psychological intervention workers, counselors, class teachers, and other student workers, and improves the predictability, accuracy, and effectiveness of psychological crisis intervention. RBF neural network is a method to identify the PCS of university students. Wavelet analysis is used to denoise the PCS signal of university students, and the characteristics of PCS of university students are extracted from the denoised signal, but RBF neural network is used as the modeling method. The teacher service module provides four submodules of student basic information data management, student measurement management, measurement data management, and other management. Therefore, we can introduce big data technology into the intervention process of university students' psychological crisis. By collecting and processing information such as academic performance, course selection, living conditions, family conditions, interpersonal relationships, and network activity, we can dig and analyze students' psychological state, so as to improve the predictability of students' psychological crisis and give targeted solutions.

As an example, the university's psychological management system is considered. Student/teacher service module, psychological counselor module, parent module, and administrator module are the four modules of the existing psychological management system. Student basic information data management, student measurement management, measurement data management, and other management are the four submodules of the teacher service module. Teachers can filter, query, sort, modify, print, and delete data in the measurement results management module. Researchers collect data on university students' mental health status using clinical scales, psychological investigations, daily outpatient services, and other methods, but the results are rarely shared with counselors, class teachers, and other student workers in the traditional mode of psychological crisis. Furthermore, aside from the aforementioned methods of obtaining psychological data, psychological workers may find it difficult to obtain data from other departments, or they may be unable to mine and process data efficiently. Some students will beautify and cover up problems from a quality standpoint. Furthermore, the information gathered in this manner is primarily stored in a static format, making it difficult to track students' development effectively. Furthermore, college students' psychology is insufficiently

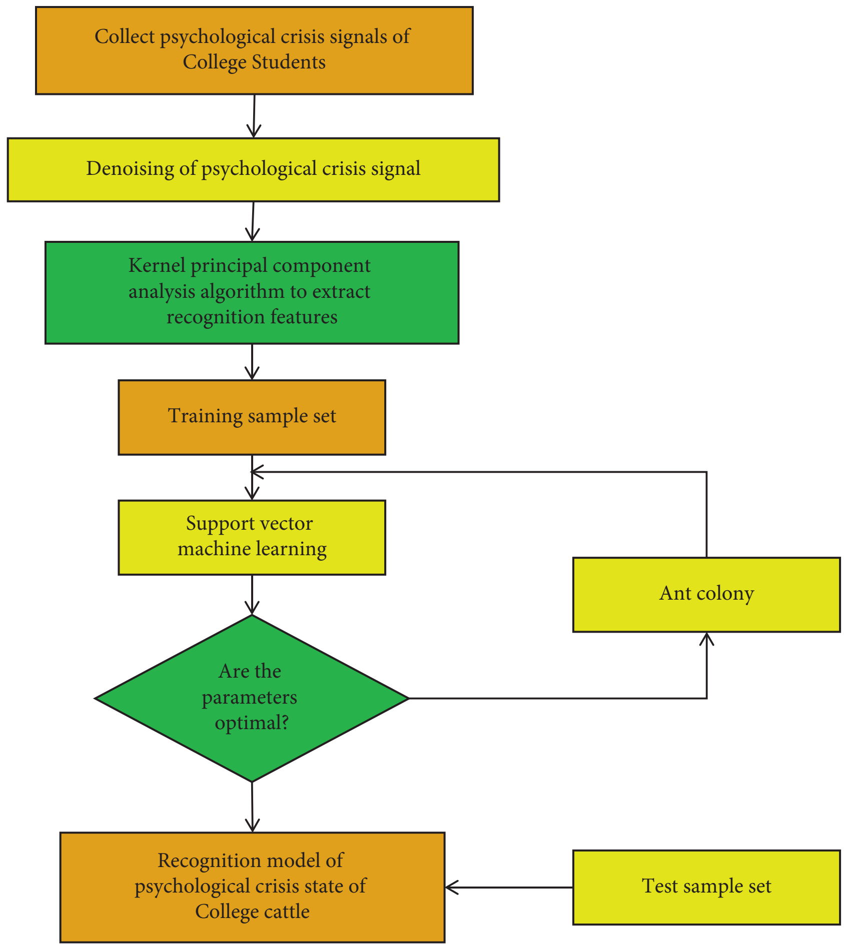

Figure 3: Process of identifying university students' PCS by DM.

mature. The psychological state will fluctuate as a result of unexpected events and environmental changes in a complicated social environment. The complex averaging operation is transformed into a functional regular operation, greatly reducing the calculation time for university students' PCS identification and allowing for better network information data interaction. Finally, a model is added to the neural network algorithm to fill in the gaps. When Hopfield fails to meet the objective function's requirements, the penalty function structure can be used to control the objective function of identifying psychological crises among university students, lowering the error rate, and making network maintenance easier. Furthermore, aside from the aforementioned methods of obtaining psychological data, psychological workers may find it difficult to obtain data from other departments, or they may be unable to mine and process data efficiently.

In the process of university students' growth, we should always give them the correct education. In the process of crisis, we should provide more help and attention to university students, provide multifaceted and multiangle social support, and guide university students to actively deal with a hidden psychological crisis. The data of students in school are distributed in various departments of the school, such as the number of students failing courses, elective courses, and punishment in the Academic Affairs Office. In the student office, students participate in social practice and competitions. Psychological investigation, consultation room, and clinical scale are all available at the psychological center. Tuition payments and student loans are handled by the finance department. Students' access to dorms, campus network usage, and other logistics are all part of the logistics package. An effective educational countermeasure system is conducive to effectively preventing university students' hidden psychological crises, timely detecting and intervening, assisting university students in smoothly navigating the crisis, enhancing their ability to resist the crisis, while also being conducive to family and school stability and the harmonious development of society. The university students' psychological crisis status is determined using the school's student psychological management system, and the information is stored in the psychological census database. By analyzing the psychological test data of university students' psychological crisis status identification in the screening data, which stores the original data of student information, psychological work evaluates students' psychological status.

4.2. Experimental Results and Analysis. In order to reflect the fairness of the experimental results of university students' PCS identification and increase the persuasion of the results, three experiments were carried out, respectively, and three methods were selected, including Rb, and the DM algorithm is used in this study. 10 experiments were conducted for each method and were selected for each experiment and analyzed by using the university students' PCS recognition. Error recognition rate and rejection rate are shown in Figures 4–6, respectively.

The correct rate, misidentification rate, and rejection rate of university students' PCS recognition by support vector machine are 85.12 percent, 8.35 percent, and 7.8 percent, respectively, as shown in Figures 4–6. The recognition effect of university students' PCS is not satisfactory. This is due to the high amount of noise in university students' PCS signals. This method ignores noise and, to some extent, interferes with feature extraction, increasing the error rate of university students' PCS recognition. The correct rate, misidentification rate, and recognition effect of university students' PCS are not the best, with 84.67 percent, 8.27 percent, and 6.56 percent, respectively. This is because, despite the fact that this method processes the signal of a university student's PCS with noise, it removes the noise interference. Teachers can use the measurement result management module to filter, query, sort, edit, print, and delete data. The correct rate, misidentification DM algorithm, and correct rate, respectively, are 94.62 percent, 3.45 percent, and 2.53 percent. The correct rate of the DM algorithm is increased by 10.39 percent and 9.65 percent, respectively, when compared to the correct rate of the DM algorithm. To ensure operational efficiency, clear division of labor, clear objectives, and complete functions, the team must continue to promote the development of an intervention system. The information system must also be standardized. There are currently no laws or regulations governing the collection, storage, mining, or use of big data technology. Data collection and use are harmed to some extent, and no clear workflow and requirements for implementation have been established. This is because this method first preprocesses university students' PCS signals and then extracts better recognition DM technology to fit the changing characteristics of university students' PCS, resulting in a better university students' PCS recognition model, reducing university students' PCS recognition based on neural network, and verifying the superiority of the DM algorithm.

In the traditional mode of psychological crisis, researchers collect data of university students' mental health status through clinical scale, psychological investigation, daily outpatient service, etc., and the results are often not shared with counselors, class teachers, and other student workers. It mainly includes the training time and test of university students' PCS identification. In order to reflect the fairness of the experimental results of university students' PCS identification, three methods were used to carry out four experiments for comparison, and each method used was selected for each experiment for simulation test. The sample data distribution university students' PCS identification is shown in Figures 7–10.

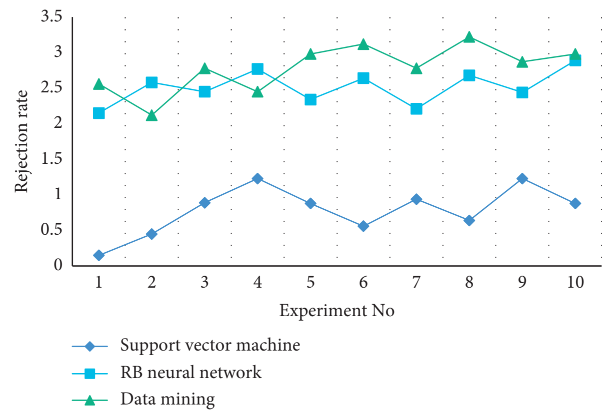

Figure 4: Rejection rate of university students' psychological crises by different methods (Experiment 1).

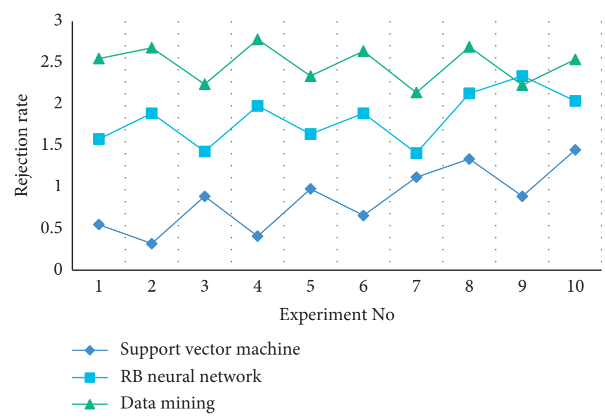

Figure 5: Rejection rate of university students' psychological crises by different methods (Experiment 2).

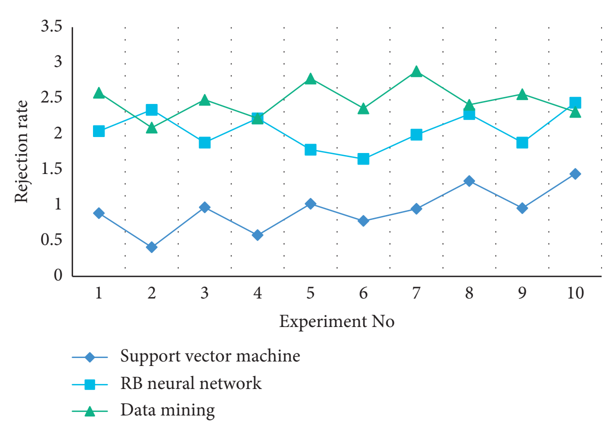

Figure 6: Rejection rate of university students' psychological crises by different methods (Experiment 3).

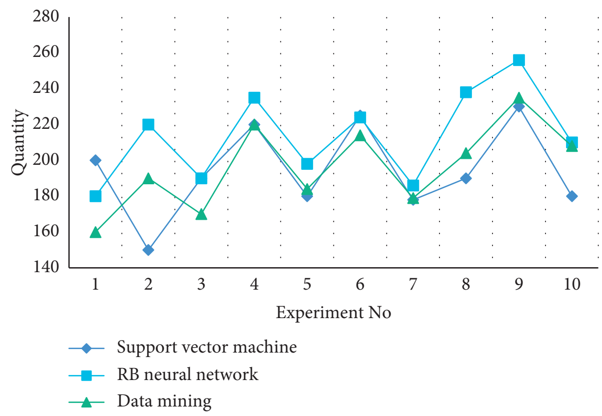

FIGURE 7: Distribution of sample data in the simulation experiment of university students' PCS identification (Experiment 1).

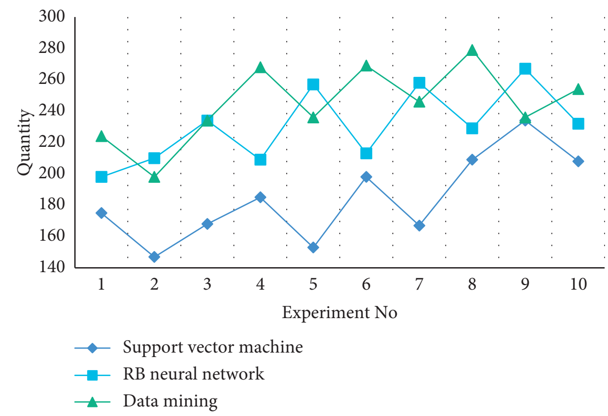

FIGURE 9: Distribution of sample data in the simulation experiment of university students' PCS identification (Experiment 3).

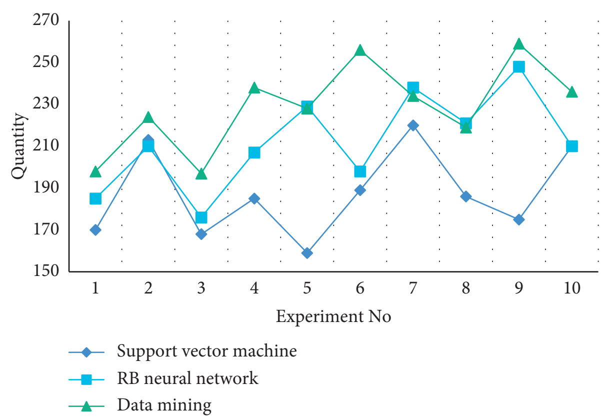

FIGURE 8: Distribution of sample data in the simulation experiment of university students' PCS identification (Experiment 2).

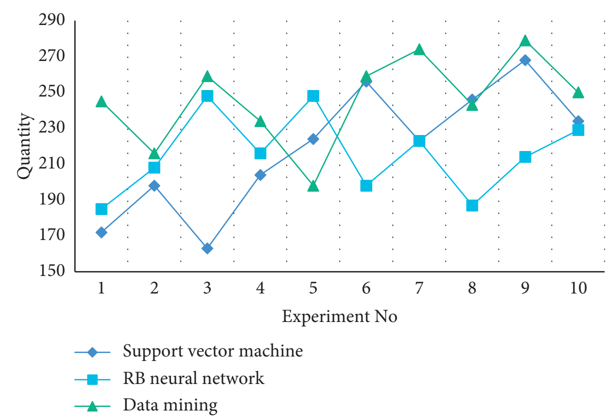

FIGURE 10: Sample data distribution diagram of university students' PCS identification simulation experiment.

The experimental results from Figure 7 to Figure 10 show that the average modeling time of university students' psychological crisis identification based on the DM algorithm is 18.03s, the network is 86.5s, and 38.47s, respectively. Psychological scale is widely used as a standardized work to evaluate the mental health level of university students, primarily for the investigation and research of university students' mental health. The general survey of newly enrolled students' mental health aims to identify students with psychological problems and assess the mental health of university students. The scale, as a test of students' psychological states, has a direct impact on students, and the scale's compilers are educators who use the scale to form relationships with students. Data on university students are primarily gathered in various school departments. Relevant leaders should pay enough attention to the cooperation between different departments and the data application management system in order to effectively retrieve, apply, and mine data in different departments. Schools should form a big data collection system working group that includes the security department, the school hospital, school leaders, the student affairs office, and the mental health department. Although the scale weavers considered students' characteristics to some extent in the past, they still regarded students as objects that could be used and transformed, and their inner world could be tested according to the contents of the test scale, influenced by the traditional educational concept. In reality, students' inner worlds are complex, and everyone receives different guidance information from the outside world. This has an impact on the scale's test results, and it makes it difficult to predict and screen out more problematic students. As a result, the DM algorithm reduces the modeling time for university student PCS identification, increases the speed of PCS identification for university students, and has a higher practical application value.

5. Conclusions

College students who have self-respect are more likely to accept themselves, accept their own flaws, and appreciate their own advantages, rather than feeling inferior and suppressing themselves because of their own flaws. This paper proposes a method of college students' psychological crisis identification based on data mining technology in order to achieve ideal results in psychological crisis identification. We can combine big data and optimize it through strategies such as building data feedback platform, optimizing management system, and building data collection system, in light of the shortcomings of the traditional intervention system, such as full sharing of data mining algorithms, insufficient dynamic management of data information, and inability to fully mine data. The simulation results of college students' psychological crisis state identification show that this method is a high-accuracy, short-modeling-time method of identifying college students' psychological crisis states, and the identification results can provide important information for college students' psychological managers. The information is kept in a database called the psychological census. Psychological work assesses students' mental health by examining psychological test data from college students' psychological crisis state identification in the screening data, which contains the original student data.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Improved Variable Step Size Least Mean Square Algorithm for Pipeline Noise

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In this study, we employ the active noise control (ANC) method to eliminate the low-frequency part of the noise generated by the rotation of the axial fan in heating, ventilation, and air-conditioning (HVAC) pipelines. Because the traditional variable step size least mean square (VSS-LMS) algorithm has poor tracking performance, we propose a variable step size filtered-X least mean square (FXLMS) algorithm based on the arctangent function to improve the adaptive filtering method of the convergence speed and noise cancellation effect. The step size of the proposed algorithm can be adjusted according to the error. When the error signal is significant, a larger step can be obtained, and when the error is small, the step size smoothness of the algorithm can be optimized. Compared with the traditional VSS-LMS algorithm, the convergence speed of the proposed algorithm is increased by 29%, the noise reduction effect is enhanced by 19%, and the mean square error (MSE) is reduced by 23% (0.0084). In addition, we developed a hardware experimental platform based on noise characteristics. In the noise reduction test using a GB/T 5836.2-06 standard PVC pipeline, the system reduced the noise by 12–17 dB.

1. Introduction

Noise has become one of the three significant pollutants that cannot be ignored globally due to the development of modern industry and the constant improvement of people's desires for a higher quality of life. In heating, ventilation, and air-conditioning (HVAC) systems [1], the noise generated during using compressors and axial flow fans is transmitted indoors through air pipelines, severely affecting people's production and life [2]. National laws and regulations have become more stringent regarding noise control requirements that affect public health. Research on various methods of reducing pipeline noise is significant for residential buildings, shopping malls, office buildings, factory workshops, and other comprehensive places greatly affected by noise [3]. Traditional noise control techniques adopt porous material sound absorption or baffle sound insulation to reduce pipe noise. Sound absorption and insulation only reduce mid and high-frequency noise but not low-frequency noise [4]. Active noise control (ANC) technology can be widely used in noisy environments because of its effectiveness in low-frequency noise control.

In 1980, Morgan [5] proposed the filtered-X least mean square (FXLMS) method based on the least mean square (LMS) algorithm. In 2015, Ardekani et al. [6] modified the instantaneous gradient estimate by introducing the secondary path (SP) model to employ the FXLMS algorithm in ANC systems. In 2015, Zhou et al. [7] proposed a novel variable step size strategy for adaptive filtering algorithms, which depends on the sigmoid variable step size LMS (SVS-LMS) algorithm. Because the change in step size is not smooth enough, the algorithm generates larger MSEs. In 2016, Wang et al. [8] proposed a sigmoid function called the antiinterference variable step size LMS (AVSS-LMS) adaptive filtering algorithm. In 2019, Salman et al. [9] proposed adding l_0 or l_1-norm penalty term to the cost function of the traditional LMS algorithm. Salman used the arctangent and sign functions to constrain weights in the iterative process of the filter weights to increase the sparsity of the LMS algorithm and further improve its convergence in impulse noise environments. In 2020, Bershad et al. [10] developed a new variable step size NLMS based on switched piecewise functions. Although the convergence speed is improved using the characteristics of each stage, at the beginning of the iteration, the algorithm still needs to set a fixed step size, which reduces the weakening effect of the sensor and environmental noise on the convergence performance of the algorithm. The improved method can reduce the steady-state error of convergence, but the improvement of convergence speed is limited. Since Salman's method is implemented by adding a penalty to the cost function, the adjustment of weights is delayed, and the penalty function is independent of the size of the error. Although the improved method is highly stable, the convergence effect is not ideal.

In this study, we suggested an optimized step change strategy for the VSS-LMS algorithm based on the ideas and research methodologies of Wang et al. [8], Salman et al. [9], and Bershad et al. [10]. We propose a variable step size FXLMS algorithm based on the arctangent function. The improved algorithm uses an inverse tangent function to link the error to the step size for the complex transformation rule of the step size in the VSS algorithm, and the transformed step size will find the optimum within a stable convergence range and does not require any new information for prediction. This optimization process is fully autonomous and does not require any perceived intervention, and the noise in the pipeline can be judged adaptively and effectively eliminated. The optimized convergence speed allows the system to adapt faster to changes in the external environment. Better robustness indicates that the active noise reduction system using this algorithm can be applied in a more complex environment, making the method more widely applicable to noise reduction in HAVC pipelines. The proposed algorithm improves the convergence speed of ANC and ensures the ANC system's stability. The simulation proceeds such that the convergence speed of the algorithm can be increased by 29% compared with that of the Wang et al. [8], Salman et al. [9], and Bershad et al. [10]. VSS-LMS algorithms and the noise cancellation effect of at least 12 dB can be achieved in the ANC experiment of HVAC pipelines. Simulations and experimental investigations show that using the proposed algorithm for the low-frequency part of the noise generated by the axial fan in the pipeline has a better effect.

The rest of this study is organized as follows: Section 2 introduces the HVAC-ANC system and experimental setup employed; Section 3 presents the traditional FXLMS algorithm and analyzes the step change strategy of the VSS-LMS algorithm; Section 4 introduces the improved algorithm, and Section 5 examines the axial fan noise characteristics in HVAC pipeline; Section 6 presents the algorithm simulation and experimental results; Section 7 presents the conclusion of the study.

2. HVAC-ANC System

2.1. HVAC System. People's concerns about the health threats of $PM_{2.5}$, $PM_{1.0}$, and other particulate pollutants, allergens, formaldehyde, total volatile organic compounds (TVOCs), household odors, and gaseous contaminants in the surrounding air driving forces for developing indoor air treatment and purification markets. An HVAC system is a technology for home environment amenities [11, 12]. The HVAC system provides thermal comfort and acceptable indoor air quality, including room temperature control, oxygen supplementation, and moisture removal. Figure 1 shows an HVAC system mainly composed of axial fans, HVAC pipelines, air filters, heating, and cooling units.

There are many noise sources in the pipeline, but their noise characteristics also have certain similarities because different systems have similar structures [13]. We analyze the main noise sources in the axial fan of an HVAC system, and some useful information can be provided for the design of an ANC system. Figure 2 shows the feedforward ANC system in an air pipeline. The reference microphone collects the noise sound wave $P1$, and the controller outputs a control signal to the secondary speaker to generate an antinoise sound wave $P2$. Then, the error microphone receives the synthesized sound waves $P1$ and $P2$ and feeds them back to the controller. From the combined sound energy density, when the phase difference between $P1$ and $P2$ is 180°, the combined sound energy density is the smallest. When the amplitudes of the sound waves $P1$ and $P2$ are equal, the energy of the sound wave reaching the error microphone is zero, achieving the purpose of active noise reduction.

2.2. Simulation and Experimental Setup. MATLAB 2019 and COMSOL Multiphysics 5.5 are used to simulate the algorithm. The input signal is Gaussian white noise plus sinusoidal at the frequency of 50 Hz. The sample number is set as n, and the expected signal is a single frequency sinusoidal signal, as shown in Figure 3. Five comparison algorithms, including the proposed, fixed step size FXLMS, piecewise LMS, AVSS-LMS, and Salman algorithm, are used for comparison. The simulation experiment compares the convergence speed, MSE, and noise cancellation effect of the five algorithms. It is obvious from Figure 3 that the proposed algorithm can eliminate the random noise loaded in the sinusoidal signal, and the recovered signal has a good effect.

The experimental computer platform is shown in Figure 4. A polyvinyl chloride (PVC) pipeline following GB/T5836.2-06 standard was used in the experiment. The pipe is $820\,mm \times 110\,mm \times 110\,mm$ in size, and the size of the tee connection is 110 mm. The test system uses a Yamaha-UR44 sound card, two Superlux-ECM999 standard acoustic measurement microphones, and two Philips monitor speakers. We use one monitoring speaker placed at the end of the pipe to generate test noise and the other speaker placed at the pipe tee to generate the cancellation sound waves. The reference microphone is located near the noise source during the test, and the error microphone is located behind the cancellation speaker. The position of the microphone will have a certain impact on the noise cancellation effect. It can have a good effect only after the Gaussian white noise is used for modeling. In practical use, once the modeling is completed, the position between the microphone and the speaker cannot change; otherwise, the system will be unstable.

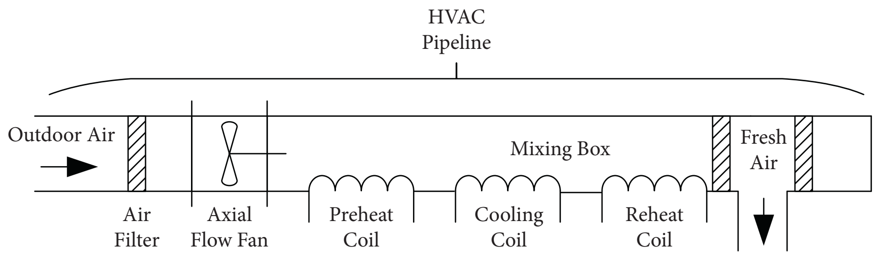

Figure 1: Schematic diagram of an HVAC system.

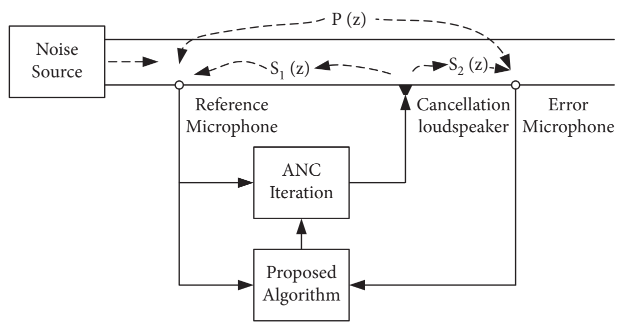

Figure 2: Feedforward ANC system in an HVAC pipeline.

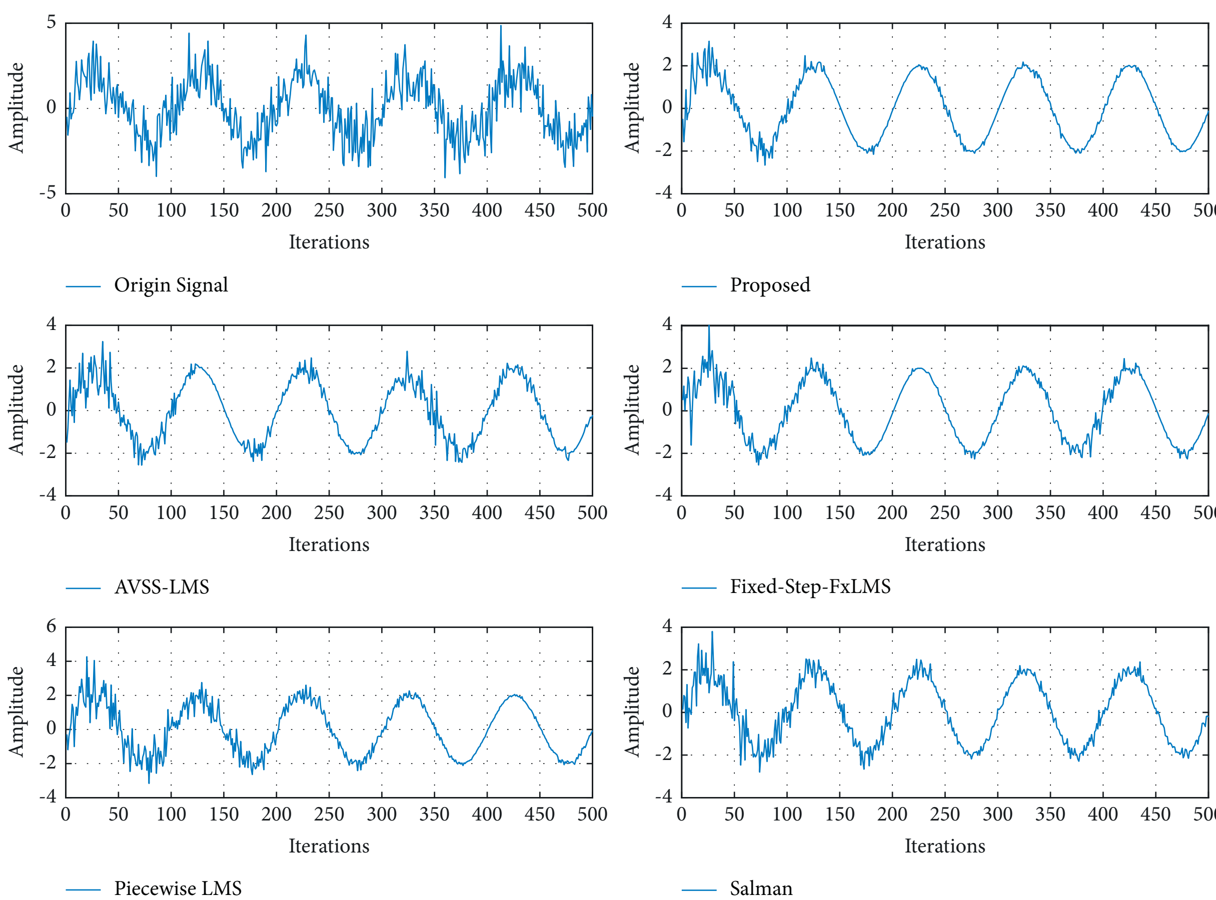

Figure 3: Comparison of five noise reduction methods.

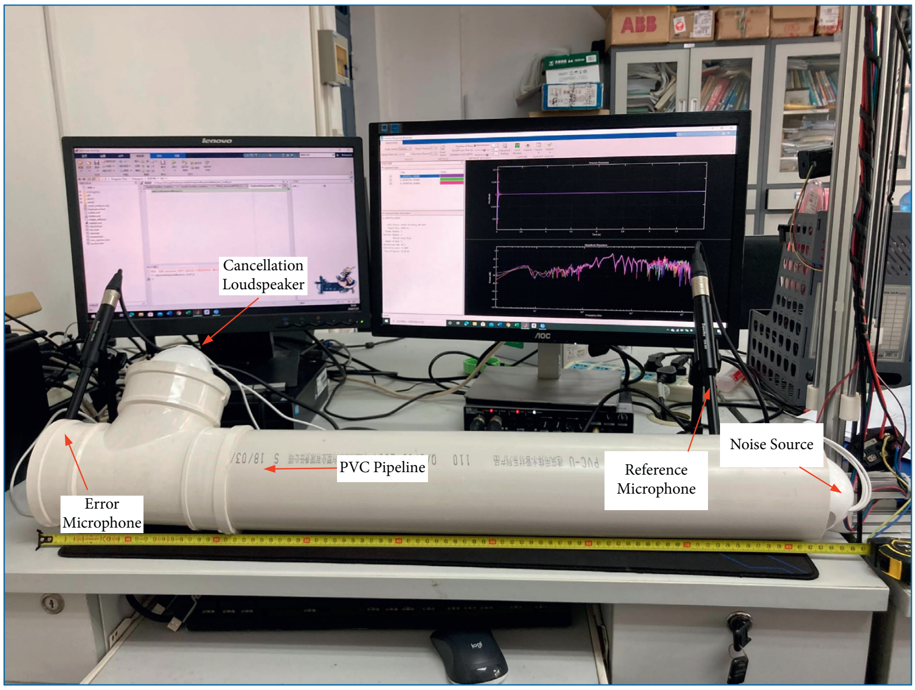

Figure 4: The experimental platform of a pipeline noise control.

3. Active Noise Control Methods

3.1. Fixed Step Size FXLMS Algorithm. The FXLMS algorithm modifies the error gradient estimation; hence, it is always used in pipeline ANC systems. Figure 5 shows a block diagram of the ANC system based on the FXLMS algorithm for air pipeline.

We can see in Figure 5 that $\mathbf{d}(n)$ denotes the desired signal, $\mathbf{x}(n)$ denotes the input signal, $\mathbf{u}(n)$ denotes the output signal, $\mathbf{e}(n)$ denotes the error between $\mathbf{y}(n)$ and $\mathbf{d}(n)$, and $\mathbf{w}(z)$ denotes the weight coefficient of the filter. The FXLMS algorithm employs the Wiener filter [14]. The Wiener filter is a linear optimal discrete filter. By calculating the autocorrelation matrix $R = E[\mathbf{u}(n)\mathbf{u}^H(n)]$ and cross-correlation matrix $p = E[\mathbf{u}(n)\mathbf{d} * (n)]$, the filter with the smallest MSE can be obtained [15]. In order to obtain the optimal tap weight, the cost function is set as follows:

$$\begin{aligned}\xi = E\left[d^2(n)\right] - w^T E[x(n)d(n)] - E\left[d(n)x^T(n)\right]w \\ + w^T E\left[x(n)x^T(n)\right]w.\end{aligned} \tag{1}$$

The steps of the FXLMS algorithm are summarized as follows:

(a) The reference and error microphones collect the reference input signal $\mathbf{x}(n)$ and error signal $\mathbf{e}(n)$, respectively

(b) The output signal $\mathbf{u}(n)$ of the FIR filter with a length of M is calculated, and the output signal $\mathbf{u}(n)$ drives the cancellation loudspeaker.

$$u(n) = \sum_{i=0}^{M-1} w_i(n)x(n-i). \tag{2}$$

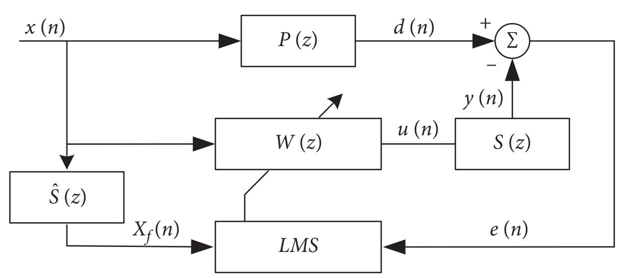

Figure 5: Feedforward FXLMS algorithm for an air pipeline.

(c) The filtered-X signal $\mathbf{x}_f(n)$ is calculated as the input signal of the LMS algorithm, where $\hat{s}_i(n)$ is the i^{th} impulse response coefficient of the SP $\hat{S}(z)$ model at time n.

$$x_f(n) = \sum_{i=0}^{M-1} \hat{s}_i(n)x(n-i). \tag{3}$$

(d) The iteration is repeated until the cost function $J(n)$ is minimized. Formula (5) indicates that the gradient of the cost function is obtained, and formula (6) indicates that the tap of the filter is optimized in the opposite direction of the gradient.

$$J(n) = |e(n)|^2 \approx \left(d(n) - \sum_{i=0}^{M-1} \hat{s}_i(n)u(n-i)\right)^2, \tag{4}$$

$$\nabla J_i(n) = \frac{\partial J(n)}{\partial w_i}, \tag{5}$$

$$w_i(n+1) = w_i(n) - \frac{1}{2}\mu\nabla J_i(n). \quad (6)$$

(e) Using formula (6) to renew the weight coefficients of the LMS algorithm adaptive filter iteratively,

$$W(n+1) = W(n) - 2\mu\mathbf{e}(n)\mathbf{x_f}(n), \quad (7)$$

where μ is the set convergence step size, and $e(n)$ is the error signal at the first iteration $e(0) = 0$. The step is fixed in the original LMS algorithm [16]. However, the inherent limitation of the fixed μ needs an adjustment between fast convergence rate and limited misalignment. The step size range is expressed as the following formula to maintain the stability of the FXLMS algorithm.

$$0 < \mu < \frac{2}{\sum_{i=0}^{M-1}\left(x_f(n-i)\right)^2}. \quad (8)$$

The FXLMS algorithm corrects the error gradient of the LMS algorithm by adding the estimated value of the SP, so that the LMS algorithm can converge stably.

The steps of SP modeling are summarized as follows:

(a) A white noise signal is set up by the white Gaussian-noise generator used as the input $S(z)$ to drive the cancellation loudspeaker, which is also used as the input signal $\widehat{S}(z)$ and the reference input signal of the LMS algorithm

(b) The error microphone collects the output signal of the cancellation loudspeaker as $y(n)$

(c) The output signal $\widehat{y}(n)$ of the SP estimation model $\widehat{S}(z)$ is calculated as

$$\widehat{y}(n) = \sum_{i=0}^{M-1}\widehat{s}_i(n)u(n-i). \quad (9)$$

(d) The output variation between the actual path signal $y(n)$ and estimated path model $\widehat{y}(n)$ is calculated as

$$e(n) = y(n) - \widehat{y}(n). \quad (10)$$

(e) The LMS algorithm updates the SP model of the adaptive filter as follows

$$s_i(n+1) = s_i(n) + \mu e(n)\mu(n-i), \quad i = 0, 1, 2, \ldots, M-1. \quad (11)$$

(f) The above process is repeated until the error signal $e(n) \approx 0$, and the coefficient of $\widehat{S}(z)$ for the FXLMS algorithm is stored.

3.2. Variable Step Size LMS Algorithm. The VSS adaptive filtering algorithm uses a variable step factor $\mu(n)$. Changing the step factor can increase the convergence speed of the adaptive algorithm and reduce MSE. At the beginning of the algorithm or when $J(n)$ is large, a larger step size factor $\mu(n)$ is used to speed up the convergence. When the convergence phase or $J(n)$ is small, a smaller step factor is used to reduce MSE [17].

The AVSS-LMS algorithm based on the sigmoid function proposed by Wang et al. [8] is a very classic VSS-LMS algorithm, and its step size factor $\mu(n)$ is given as

$$\mu(n) = b\left(\frac{1}{1+\exp(-aE|e(n-1)e(n)|)} - 0.5\right). \quad (12)$$

The parameter a is used to handle the steepness of the sigmoid function and b handles the value range of function. In this case, formula (7) can be expressed as

$$W(n+1) = W(n) - 2\mu(n)x_f(n). \quad (13)$$

Compared with the step size μ of the FXLMS algorithm, the iterative step size $\mu(n)$ of the AVSS-LMS algorithm is variable. The initial stage of the algorithm convergence $\mu(n)$ has a high rate, implying a high convergence speed. In the stable stage, $\mu(n)$ takes a smaller value. When b is 0.02, 0.01, or 0.005 and a is 5, 2, 1, or 0.5, the step size of the AVSS-LMS algorithm varies with the error.

Figure 6 shows the step size change strategy of the AVSS-LMS algorithm. The AVSS-LMS algorithm solves the problem that the stability and convergence speed always contradict each other. However, the step size of the AVSS-LMS change is not smooth enough when the error is limited, and the maximum step size of the function is limited by this problem. Here, the arctangent function is used to transform the error nonlinearly. The proposed algorithm can obtain a larger step size in the introductory stage. When it is close to stability, the step size changes smoothly to obtain rapid convergence speed and limited MSE.

4. Improved Algorithm Using the Arctangent Function

Although the principles of VSS-LMS algorithms are different, they all employ the basic adjustment strategy [18–21]. Mostly, VSS-LMS algorithms use a larger step size in the introductory moment of the iteration or when the error is large to increase the convergence rate. In the stable phase of the algorithm or when the error is limited [22], a limited step size factor is used to reduce MSE. This adjustment strategy is also employed here by introducing the arctangent function to construct the nonlinear accord between the error function and step size. The improved method adds three adjustable parameters for different noises. The improved step change coefficient is given as

$$\mu(n) = b\left(\frac{3}{\left(1+\exp\ (-a|\arctan(e(n))|)^c\right)} - 1\right), \quad (14)$$

where $\mu(n)$ represents the step value obtained when the error at the time n is $e(n)$, and a, b, and c are the user-defined parameters and constants. The arctangent function is used for three reasons; it is nonlinear, bounded, and continuous. These three points can ensure the convergence and stability of the function.

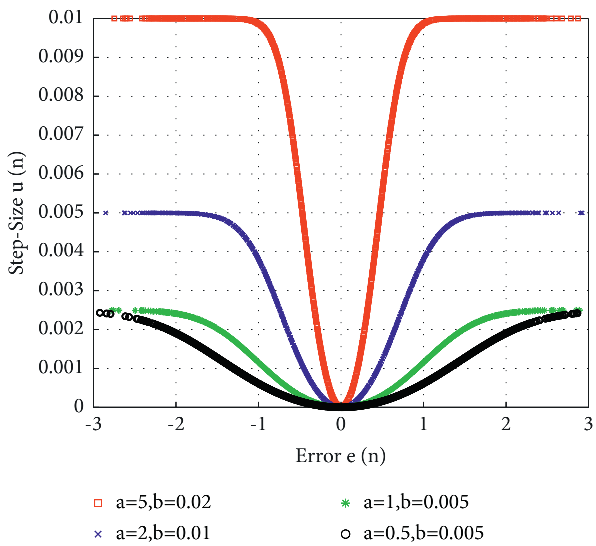

FIGURE 6: Variation of the step size of the AVSS-LMS algorithm with error.

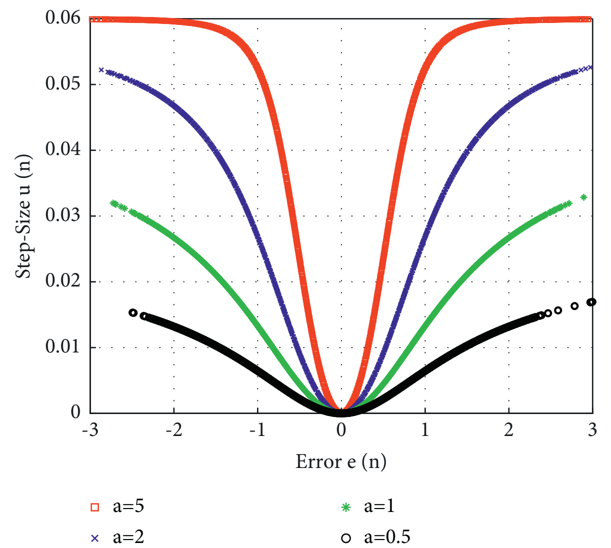

FIGURE 7: Variation of the step size of the proposed algorithm with a.

4.1. Effect of Step Size on the Algorithm. We conclude from formula (15) that increasing the step size factor can reduce the learning time and converge a little time. However, the small step length will boost the number of iterations [23], thus reducing the convergence acceleration of the algorithm.

$$\tau_{mse,\min} \approx \frac{1}{2\mu(n)\lambda_{\min}}, \tag{15}$$

where $\tau_{mse,\min}$ represents the smallest eigenvalue of the autocorrelation matrix of the input signal and $\lambda_{\min}$ represents the minimum MSE that can be obtained by the algorithm. Therefore, to solve the problem of the stability and convergence speed always contradicting each other [24] when the fixed step size adaptive filtering algorithm is tested to the active control of pipeline noise, the strategy of changing the step size is employed. Formula (16) shows that the steady-state error is directly proportional to the step size. As the step size increases, the steady-state error increases [25].

$$\varepsilon = \frac{\mu(n)}{2}\sum_{k=1}^{M}\lambda_k, \tag{16}$$

where λ_k is the eigenvalue of the autocorrelation matrix $\mathbf{u}(n)$. Formulas (15) and (16) show a contradictory relationship between the convergence rate and stability.

4.2. Effect of Parameter a on the Algorithm. Parameters b and c are fixed to investigate the effects of parameter a and step size μ of the proposed algorithm. When $b = 0.03$, $c = 2$, and $a = 5$, 2, 1, and 0.5 (Figure 7), the step size μ of the improved algorithm varies with the error $e(n)$. With an increase in a, the step variation curve gradually becomes steep. It means that a larger parameter a can make the algorithm more sensitive to error, but when a increases to a certain extent, the maximum step size of the algorithm will not continue to increase.

Figure 8 shows that as a gradually increases, the convergence speed increases rapidly. The convergence speed of the algorithm is influenced by a. As the value of a increases, the convergence speed becomes brisker, simultaneous bottom becomes sharper, and MSE increases accordingly. We can see from formula (16) that this is caused by the increase of step size. Therefore, blindly increasing parameter a is not a good strategy to improve the algorithm. It can be seen from Figure 8 that when $a > 2$, the increase in the convergence speed of the algorithm is not so obvious, so the value of parameter a cannot be set too large.

4.3. Effect of Parameter b on the Algorithm. The influence of parameter b on the step size μ of the improved algorithm is studied by fixing the parameters a and c. When the parameters $a = 1$, $c = 2$, and $b = 0.005$, 0.01, 0.03, and 0.1, the step size varies with the error, as shown in Figure 9. Parameter b directly affects the maximum step size of the algorithm. As b increases, the upper limit of the maximum step size increases, but very high values of b may increase the MSE.

As shown in Figure 10, at a smaller b, the convergence acceleration of the algorithm is greatly reduced. Therefore, to ensure the high convergence acceleration, stable convergence of the algorithm b should be adjusted according to the stable convergence conditions shown in the following formula:

$$0 < \mu < \frac{2}{\sum_{i=0}^{M-1}\left(x_f(n-i)\right)^2}. \tag{17}$$

The algorithm will not converge when the variable step size exceeds the upper limit. Therefore, the reciprocal of the input signal power is usually used to determine the upper limit of the step size.

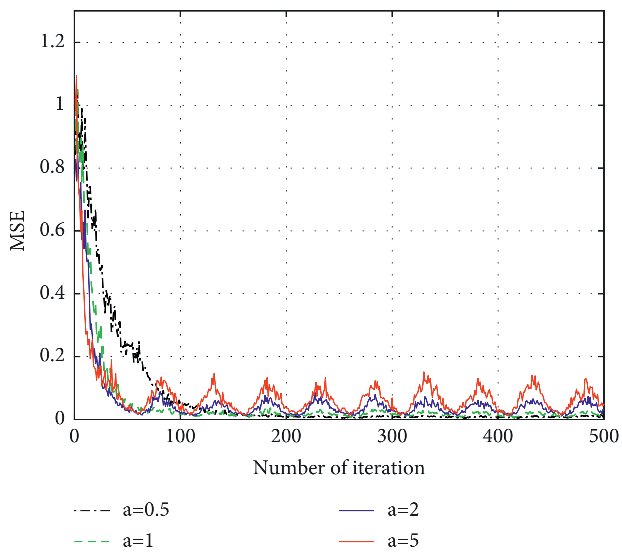

Figure 8: MSE of the proposed algorithm at different a.

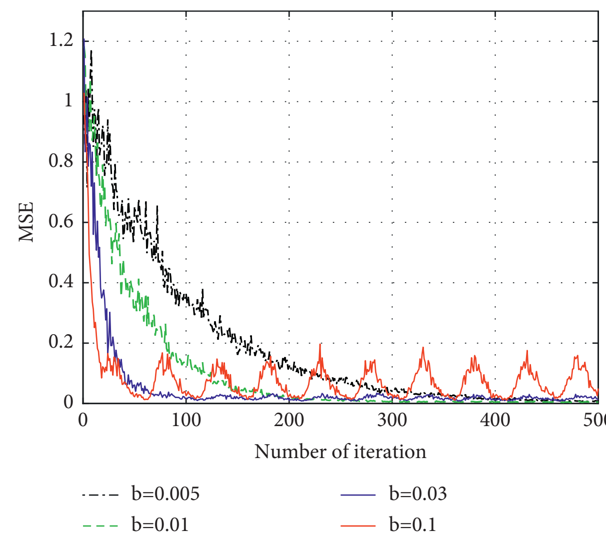

Figure 10: MSE of the proposed algorithm at different b.

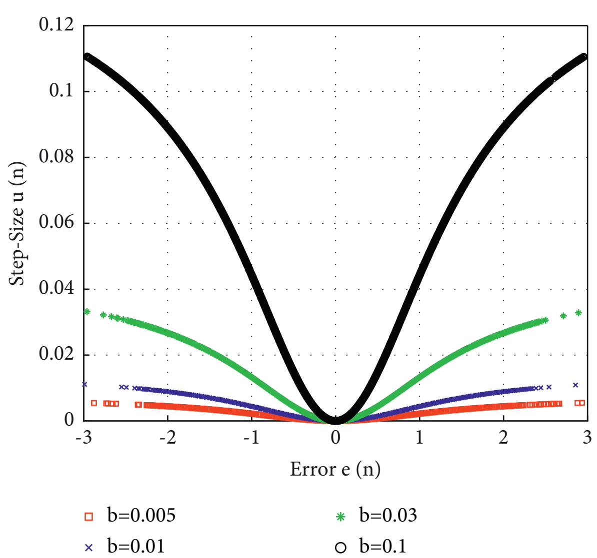

Figure 9: Variation of the step size of the proposed algorithm with b.

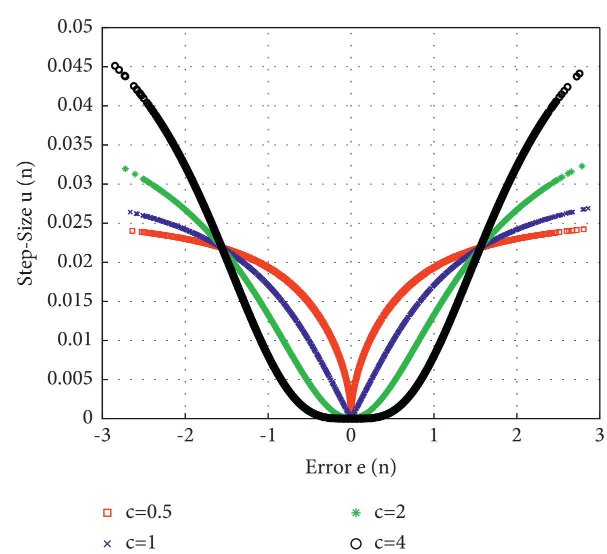

Figure 11: Variation of the step size of the proposed algorithm with c.

4.4. Effect of Parameter c on the Algorithm. The influence of c on the algorithm is studied by fixing a and c. When a, b, and c are 0.5, 1, 2, and 4, the step size varies with the error, as shown in Figure 11, and we can see that c directly affects the smoothness of the bottom of the function; the larger the value of c, the smoother bottom of the function. Without affecting the steady-state error, increasing the value of c increases the convergence speed of the algorithm to a certain extent without affecting the stability of the function. Since the value a directly affects the way of a step change, according to the variable step strategy, the value c should be greater than 1. Because exponential growth directly increases the amount of calculation (Figure 12), the convergence speed of the algorithm is not significantly increased only by adjusting the value of c. Therefore, the value of c needs to be adjusted after adjusting that of a and b.

4.5. Robustness of the Algorithm. Random noise has a severe impact on the stability of the adaptive algorithm [26]. A random addition is needed for a robust solution for the adaptive filter due to the inevitable noise in the environment, such as measurement noise and environmental modeling errors [27]. Therefore, it is necessary to introduce a random additive interference signal $v(n)$. The expected signal $d(n)$ is expressed as

$$d(n) = w_o^H(n)u(n) + v(n), \tag{18}$$

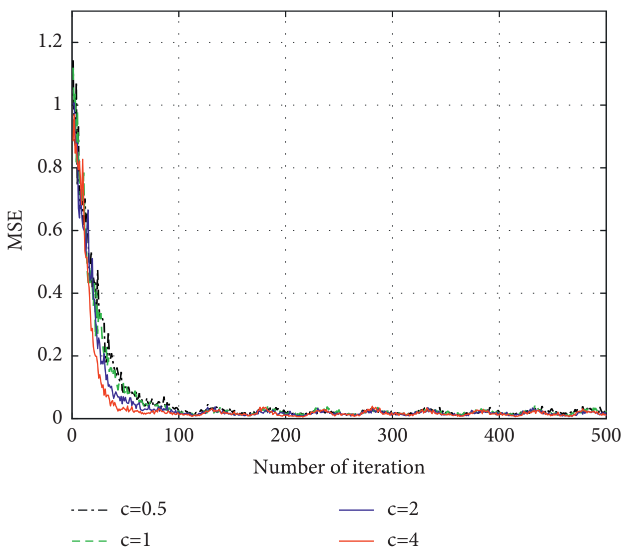

FIGURE 12: MSE of the proposed algorithm at different c.

where $w_o(n)$ is the optimal tap weight vector of the Wiener filter. However, because the environment of the system is unknown, suppose that $w_o(n)$ is estimated as $w(n)$, the expected signal can also be expressed by formula (25).

$$d(n) = w(n)u(n) + e(n). \tag{19}$$

Since the recursive estimation of $w(n)$ is strictly causal, in the adaptation cycle n, updating $w(n-1)$ to $w(n)$ depends only on the current input vector $u(n)$, and the weighted error vector $\widetilde{w}(n)$ can be defined as

$$\widetilde{w}(n) = w_o(n) - w(n). \tag{20}$$

As the measurable error signal relevant to the weighted error vector $w(n)$, the error without interference is given by

$$\begin{aligned}\xi_u(n) &= e(n) - v(n)\\ &= \left[w_o(n) - w(n)\right]^H u(n)\\ &= \widetilde{w}(n)u(n),\end{aligned} \tag{21}$$

where $v(n)$ is the random additive interference signal, $e(n)$ is the error signal, and the cause of $\xi_u(n)$ can be known from formula (20) as the deviation between the optimal solution $w_o(n)$ of the Wiener filter and the actual filter $w(n)$.

We calculate the arbitrary estimator H^{∞}, and it is necessary to calculate the worst-case energy gain from the interference [28] to the noninterference estimation error in formula (21). To obtain the bounds of the energy gain, we can obtain the following formula from the Cauchy-Schwartz theorem.

$$[\widetilde{w}(n)u(n)]^2 \le \|\widetilde{w}(n)\|^2\|u(n)\|^2. \tag{22}$$

Therefore, by taking formula (21) squared at both ends and based on the inequality shown in formula (22), the following conclusions can be drawn:

$$\left|\xi_u(n)\right|^2 \le \|\widetilde{w}(n)\|^2\|u(n)\|^2. \tag{23}$$

Add interference $v(n)$ to the right of formula (23), and since $\mu(n)$ is always positive and less than 1, we can obtain the inequality shown in formula.

$$\left|\xi_n(n)\right|^2 \le \mu^{-1}(n)\|\widetilde{w}(n)\|^2 + |v(n)|^2. \tag{24}$$

When the algorithm converges, it is necessary to ensure that $\widetilde{w}(n+1) \le \widetilde{w}(n)$, so the inequality shown in formula (25) can be derived from formula (24):

$$\mu^{-1}(n)\|\widetilde{w}(n+1)\|^2 + \left|\xi_\mu(n)\right|^2 \le \mu^{-1}(n)\|\widetilde{w}(n)\|^2 + |v(n)|^2. \tag{25}$$

Since the estimated value of the tap $\widetilde{w}(n)$ is monotonically decreasing, we can obtain the inequality shown in the following formula:

$$\mu^{-1}(n)\|\widetilde{w}(n)\|^2 + \sum_{n=0}^{N}\left|\xi_u(n)\right|^2 \le \mu^{-1}(n)\|\widetilde{w}(0)\|^2 + \sum_{n=0}^{N}|v(n)|^2. \tag{26}$$

If formula (23) is brought into formula (26), there must be an inequality shown in formula (27), which shows that the proposed method will have good robustness when the following conditions are met.

$$\sum_{n=0}^{N}\left|\xi_u(n)\right|^2 \le \mu^{-1}\|\widetilde{w}(0)\|^2 + \sum_{n=0}^{N}|v(n)|^2. \tag{27}$$

The right side of formula (27) can be divided to the left, and the symbol γ^2 represents the maximum energy gain.

$$\gamma^2(\mu(n)) = \underset{w,v\in H^2}{SUP}\frac{\sum_{n=0}^{N}\left|\xi_u(n)\right|^2}{\mu^{-1}\|\widetilde{w}(0)\|^2 + \sum_{n=0}^{N}|v(n)|^2}, \tag{28}$$

where superscript 2 represents the second norm, and sup means the supermum upper bound. Assuming the specific interference sequence is $v(n) = -\xi_u(n)$, so formula (28) can be expressed as

$$\gamma^2(\mu(n)) = \frac{\sum_{n=0}^{N}\left|\xi_u(n)\right|^2}{\mu^{-1}\|\widetilde{w}(0)\|^2 + \sum_{n=0}^{N}\left|\xi_u(n)\right|^2}. \tag{29}$$

Therefore, when the power of the input signal $u(n)$ is limited, it is $\lim_{N\to\infty}\sum_{n=0}^{N}\|u(n)\|^2 < \infty$. For any given normal number Δ, a parameter vector $w(n)$, and an integer N, formula (21) can be expressed as

$$\begin{aligned}\sum_{n=0}^{N}\left|\xi_u(n)\right|^2 &= \sum_{n=0}^{N}\left|\left(w_o(n) - w(n)\right)^H u(n)\right|^2\\ &\ge \frac{1}{\Delta\mu(n)}\left\|w_o(n) - w(0)\right\|^2\\ &= \frac{1}{\Delta\mu}\|\widetilde{w}(0)\|^2.\end{aligned} \tag{30}$$

By eliminating the common term of formula (29) and keeping the bounds of γ^2, we can get the result

$$\frac{1}{1+\Delta} \leq \gamma^2 \leq 1. \tag{31}$$

Formula (31) shows that as the constant Δ tends to 0, the maximum energy of the improved algorithm will never exceed 1. Therefore, the proposed algorithm is H^{∞} optimal, and the system has good stability [29].

5. Characteristics of Pipeline Noise

There are many noise sources in a pipeline. However, due to the similarity in the structure of different systems, their noise characteristics are also similar [30]. The rotating noise is the main source of pipeline noise, and its fundamental frequency can be determined by the number of fan blades and motor velocity [31, 32]. The noise produced by the axial flow fan is more than 25 dB (Table 1). Here, we use the POPULA-JD100 axial fan (Figure 13).

The noise generated by the axial fan can be calculated using the following formulas [33]:

$$\mathrm{PWL} = 56\lg V + 10\lg\left(p_s c_m^{0.6} LZ\right) - 15.23, \tag{32}$$

$$V = 2\pi r\left(\frac{n}{60}\right), \tag{33}$$

$$p_s = p_i + p_d, \tag{34}$$

$$\begin{aligned}\mathrm{SPL} = {} & 56\lg V + 10\lg\left(p_s c_m^{0.6} \mathrm{LZ}\right) - 15.23 \\ & - 20\lg(4\pi\ d) + 10.99.\end{aligned} \tag{35}$$

The static pressure $p_i = 101325\,(\mathrm{Pa})$, dynamic pressure $p_d = 274\,(\mathrm{Pa})$, motor speed $n = 2450\,(\mathrm{rpm})$, average width of the fan blade $C_m = 0.015\,(\mathrm{m})$, leaf height $L = 0.020\,(\mathrm{m})$, and the number of leaves $Z = 10$. d is the measured distance, and the constant number 15.23 is the empirical value. The simulation is performed according to formula (35). The noise of the axial fan is mainly produced by monopole, dipole, and quadrupole noise sources [34]. Monopole noise is mainly caused by a change in the gas volume [35], dipole noise by the fluctuation of the static pressure on the impeller surface, and quadrupole noise by viscous stress radiation [36]. Due to the low air velocity of the JD100 axial flow fan, the monopole noise source can be ignored, and in the case of a low Mach number, the quadrupole noise source can be ignored. Therefore, the aerodynamic noise of the JD100 axial fan is mainly a dipole noise source. Axial flow fans produce different noises under different working conditions, and their frequency, sound pressure, and speed are not linear. According to formula (35), the sound pressure spectrum distribution of JD100 axial flow fan at different distances from 0 to 2500 rpm is studied. Figure 14 shows that the fundamental frequency and harmonics of the aerodynamic noise generated by the JD100 axial flow fan gradually increase with speed. The maximum frequency of noise is obtained at a speed of 2500 rpm. The main frequency of the rotating noise is below 4 kHz, which indicates medium and low-frequency noise. It is difficult to reduce this part of noise using the passive noise reduction method. Figure 15 shows that the higher the fan speed [37], the closer the measurement distance and the greater the noise obtained. At 2500 rpm, the noise generated by the JD100 axial flow fan is not less than 30 dB when the distance is 1 m.

Noise mainly propagates through the pipe, and the shape, size, and wall material of the pipe affect sound wave propagation in the pipe [38]. To analyze this problem, first, a cylindrical coordinate system $O - r - \varphi - z$ is established for a circular pipe, as shown in Figure 16, assuming that noise is generated at z = 0 of the tube and the other end is infinitely extended. The wall of the pipe is assumed to be rigid. The acoustic field in the pipe varies in the range $r \in [0, a]$, $\varphi \in [0, 2\pi]$, and $z \in [0, \infty]$.

Assuming the relationship between the generator's sound pressure and time is simple and harmonic, the sound pressure can be expressed as

$$\begin{aligned} & p(x, y, z, t) = p(x, y, z)e^{j\omega t}, \\ & \nabla^2 p(x, y, z) + k^2 p(x, y, z) = 0, \\ & \nabla^2 = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2}{\partial \varphi^2} + \frac{\partial^2}{\partial z^2}, \end{aligned} \tag{36}$$

where ∇^2 is the Laplacian of the three-dimensional cylindrical coordinate system, k is the number of waves, and c is the sound speed [39]. Then, the sound field in the rigid-walled cylindrical waveguide under excitation of the non-axisymmetric sound source is given by

$$\begin{aligned} p(r, \varphi, z, t) = {} & e^{j\omega t}\sum_n\sum_m A_{nm}J_n\left(\frac{\beta_{nm}}{a}r\right)\cdot\ \cos(n\varphi + \varphi_n) \\ & e^{-j\sqrt{k^2-(\beta_{nm}/a)^2}z}, \end{aligned} \tag{37}$$

where A_{nm} is the constant determined by the boundary conditions, n and m are the circumferential and radial modal numbers, respectively, a is the radius of the pipe, and $J_n(x)$ is the first Bessel function. The value of β_{nm} can be obtained from Table 2.

On the cross-section of a circular tube, the normal mode wave of order (n, m) determined at different values of β_{nm} would result in different acoustic characteristics [40]. The sound pressure in a pipe is the superposition of the sound pressure components of each model. From formula (39), we can obtain an important property of sound wave propagation in a circular tube, that is, the existence of cutoff frequency n, as

$$\sqrt{k^2 - \left(\frac{\beta_{nm}}{a}\right)^2} < 0, \tag{38}$$

$$f_{\mathrm{cutoff}} \geq \frac{\beta_{mn}}{2\pi a}c, \tag{39}$$

$$c = \sqrt{YRT}, \tag{40}$$

Table 1: Axial fan performance parameter table.

Model (no.)	Data parameter			
	Power (W)	Air volume (m^3/h)	Pressure (Pa)	Noise (dB)
JD100	28/25	200/150	180/130	30/25
JD150	50/40	500/400	300/250	35/30
JD200	70/60	850/700	350/280	50/45
JD250	170/130	1500/1100	550/400	60/54
JD315	320/230	2300/1800	700/500	66/61

Figure 13: POPULA-JD100 axial fan.

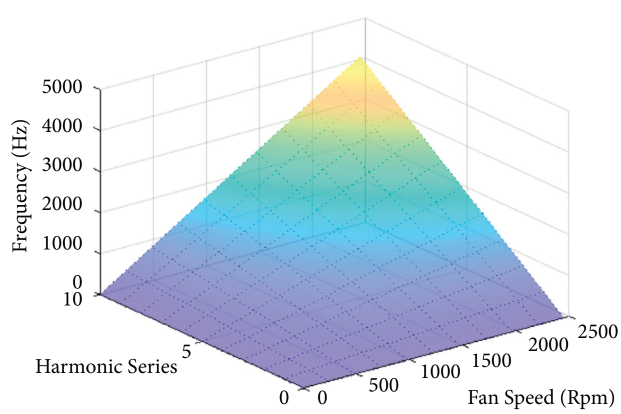

Figure 14: Relationship between speed and noise frequency of an axial fan.

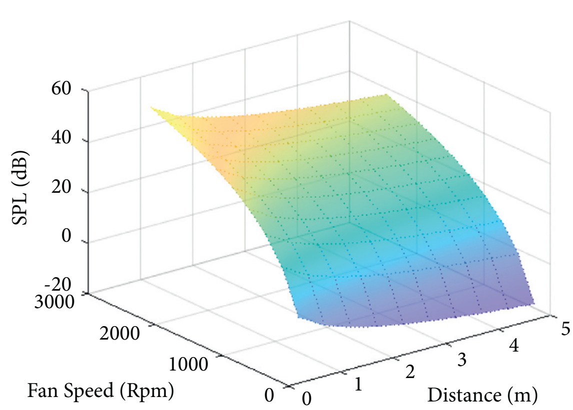

Figure 15: Relationship between noise and distance of an axial fan.

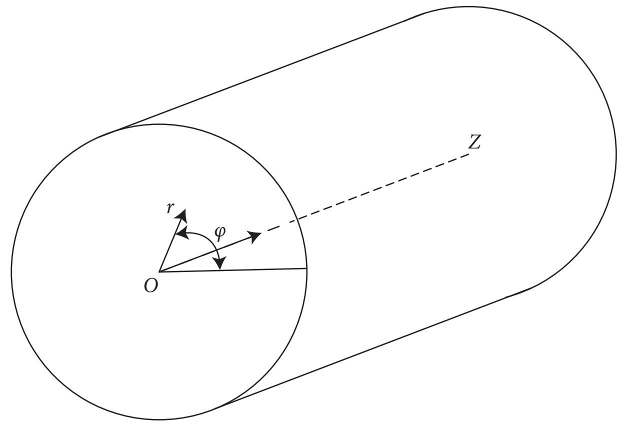

Figure 16: Circular pipe waveguide.

Table 2: β_{nm} root table.

β_{nm}	$n=0$	$n=1$	$n=2$	$n=3$	$n=4$	$n=5$
$m=0$	0	3.832	7.016	10.174	13.324	16.47
$m=1$	1.841	5.331	8.536	11.706	14.864	18.016
$m=2$	3.054	6.706	9.969	13.17	16.348	19.513
$m=3$	4.201	8.015	11.346	14.586	17.789	20.973
$m=4$	5.318	9.282	12.682	15.964	19.196	22.401
$m=5$	6.415	13.987	13.987	17.313	20.576	23.804

where ϒ is the specific heat ratio (for air ϒ = 1.4), T is the thermodynamic temperature of the gas in K, and R is the gas constant (usually $R = 287\,\mathrm{J(kg \cdot K)}$). If there is no pressure change during a specific use, only the temperature is usually considered. In the pipeline, the sound wave frequency is smaller than the cutoff frequency that can propagate by formula (39), and the sound wave frequency larger than the cutoff frequency will decay exponentially. The noise higher than the cutoff frequency does not need ANC [41]. The frequency of the pipeline is a result of the superposition of multiple groups of β_{nm} values that can be obtained from Table 2. In the finite element analysis of the pipeline [42], white noise is used to excite the simulation model, and the simulation model has the attenuation effect of excitation sound waves at different frequencies (350–3600 Hz), as shown in Figure 17.

The simulation of the sound wave transmission aspect of the pipeline shows that, for the HVAC-ANC system, high-frequency noise generated by the axial fan is quickly attenuated in the pipeline. Therefore, the ANC system can only handle frequencies below 4 kHz at the end of the pipeline. Low-frequency noise can reduce the acquisition bandwidth of ADC [43], reduce the number of iterations of the ANC system, and improve the noise cancellation effect of the algorithm.

6. Experimental Results and Discussion

The proposed algorithm is compared with the fixed step size FXLMS, piecewise LMS, AVSS-LMS, and Salman algorithms in the simulation. Table 3 provides the parameter setting. The test input signal is composed of Gaussian white noise and sinusoidal signal. The system has 10000 iterations, and the signal noise ratio (SNR) is 20 dB.

Figure 18 shows the step sizes of the five algorithms very differently according to the error signal size variation trend. The proposed algorithm can obtain the maximum step size when the error is large. According to formula (15), the larger the step size, the higher the convergence speed of the algorithm. Therefore, the algorithm is characterized by high convergence speed when the error signal is large, and the step size obtained from the piecewise LMS algorithm occurs second. When the error signal is small, the step change of the proposed algorithm is smoother than that of the AVSS-LMS and piecewise LMS algorithms. Formula (16) shows that the steady-state error obtained with a smaller step size becomes smaller as it approaches stability. Therefore, compared with the AVSS-LMS and piecewise LMS algorithms, the proposed method has less MSE. Formula (30) shows that the proposed method has a high convergence speed and reduced MSE. It also has good antiinterference ability and can converge stably.

Figure 19 shows that the five algorithms can converge and filter out the noise, but their convergence speed and MSE are different; the speed and MSE of the proposed algorithm are better than those of the other four algorithms. Figure 19 shows that, among other algorithms, the performance of the piecewise LMS algorithm is closest to the convergence performance of the proposed algorithm. The proposed and piecewise LMS algorithms have good theoretical tracking performance on noise, but the piecewise points of the piecewise LMS algorithm affect the results of the algorithm. In order to improve the performance of the piecewise LMS algorithm, much time and energy are needed

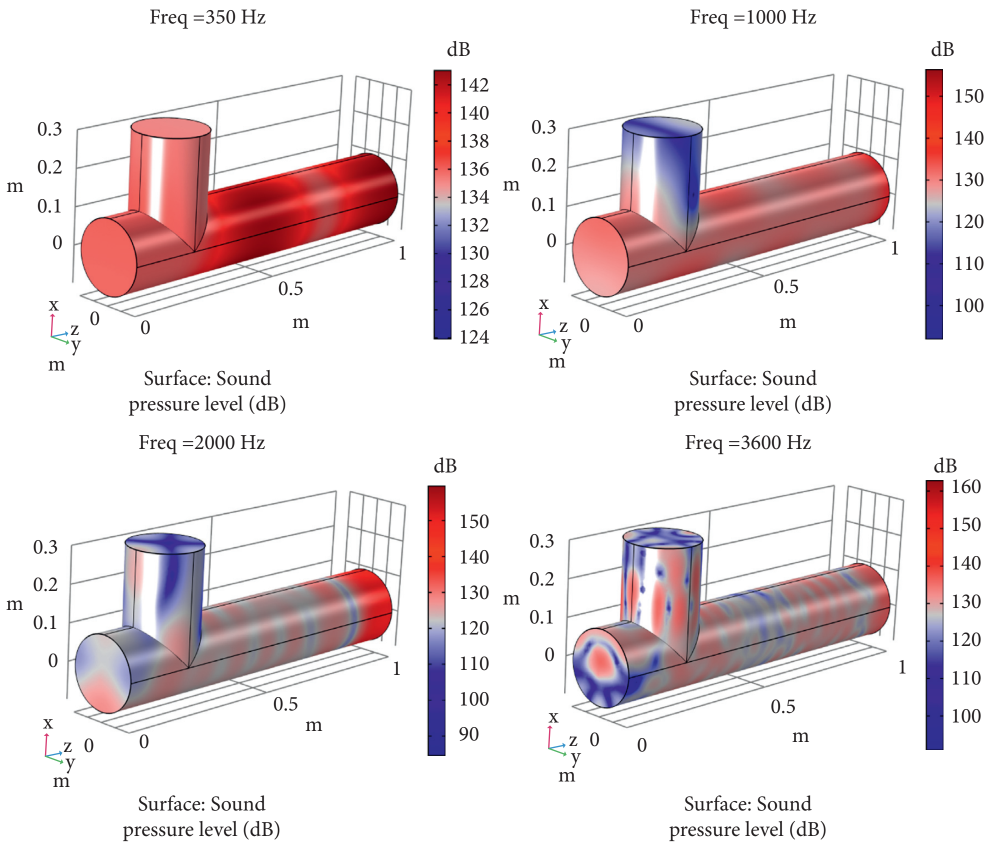

Figure 17: Sound wave transmission simulation in a PVC pipeline.

Table 3: Simulation parameters for the proposed algorithm and other algorithm.

Algorithm	Variable step	Parameter
AVSS-LMS	$\mu(n) = b(1/1 + \exp(-aE\|e(n-1)e(n)\|) - 0.5)$	$a = 0.97, b = 0.03$
Fixed step FXLMS	μ	$\mu = 0.01$
Piecewise LMS	$\begin{cases} \mu = k,\ 0 \le n \le \text{sample length}/5 \\ \mu(n) = b(1 - \exp(-a * \|e^2(n)\|)), 0.001 < \|e^2(n)\| \le 0.01 \\ \mu(n) = b(-1 + \sec(a * \|e(n)\|)),\ 0 \le \|e^2(n)\| \le 0.001 \end{cases}$	$k = 0.03,\ a = 0.97,\ b = 0.03$
Salman	$\mu(n) = \lambda(\operatorname{sgn}(w(n))/(1 + b\|w(n)\| + b^2\|w(n)\|^2))$	$\lambda = 0.02, a = 0.97, b = 0.03$
Proposed	$\mu(n) = b(3/(1 + \exp\ (-a\|\arctan(e(n))\|)^c) - 1)$	$a = 0.97, b = 0.03, c = 4$

to fine-tune the parameters. Considering MSE, the Salman algorithm has a low MSE after stability. The proposed method can have MSE as low as that of the Salman algorithm, but its convergence speed is much higher than that of other algorithms. Notably, the MSE of the proposed algorithm shows a further downward trend.

Table 3 provides that the Salman algorithm is also a variable step size algorithm, but Figure 18 shows that the variable step size strategy of the Salman algorithm is not causally related to the error signal. The Salman algorithm uses a penalty weight to adjust the step size. It makes the weight lag, so it does not have a large step at the beginning of iterations. Its convergence speed is much lower than the AVSS-LMS and piecewise LMS algorithms (Figure 19). However, it can obtain smaller MSE than the AVSS-LMS and piecewise LMS algorithms when the number of iterations increases and it converges stably. The Salman algorithm can obtain the same noise cancellation effect as the proposed algorithm when it is employed in the processing of HVAC pipeline noise. Still, its ability to track abrupt noise is not as strong as that of the proposed algorithm.

ANC-OFF in Figure 20 is the noise collected by the microphone at the outlet of the PVC pipe, and it can be seen that part of the noise generated by the axial fan, part of the rotating noise has a frequency, which can be deduced from formula (32), while the other part belongs to the random noise, and this part of the noise belongs to the more difficult to eliminate. From ANC-ON shown in Figure 20, it can be seen that the signal amplitude of the noise at the outlet of the PVC pipe can be reduced by about 17 dB after a very short time, indicating that the proposed method has a practical effect of noise reduction. It can also be seen from the

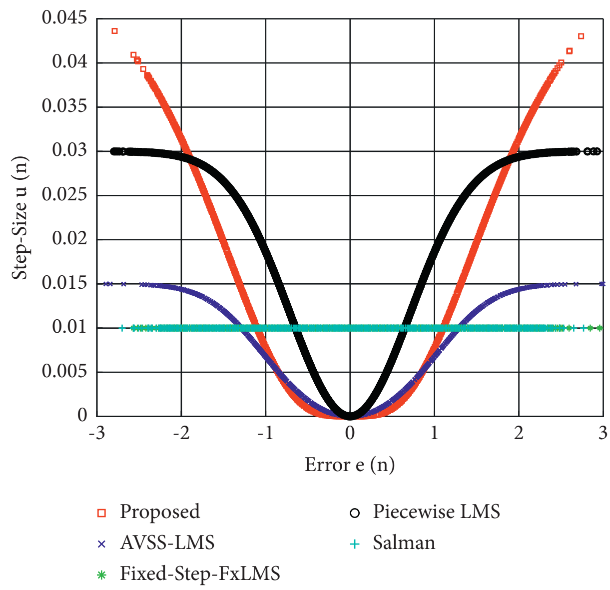

Figure 18: Comparison of step size of five noise reduction methods.

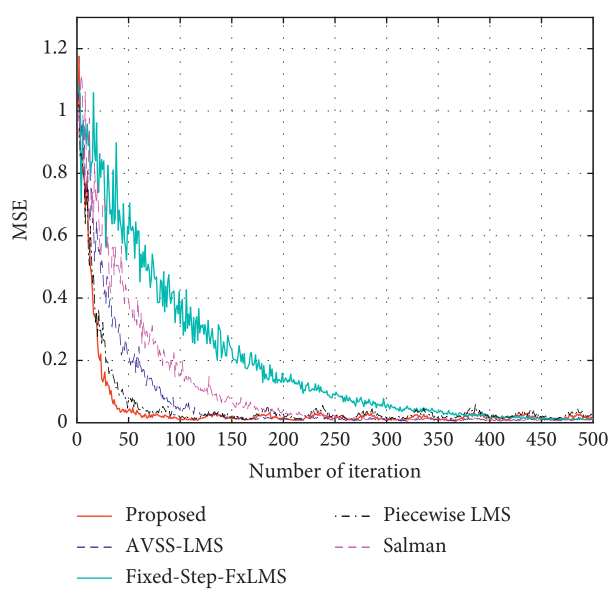

Figure 19: Comparison of MSE of five noise reduction methods.

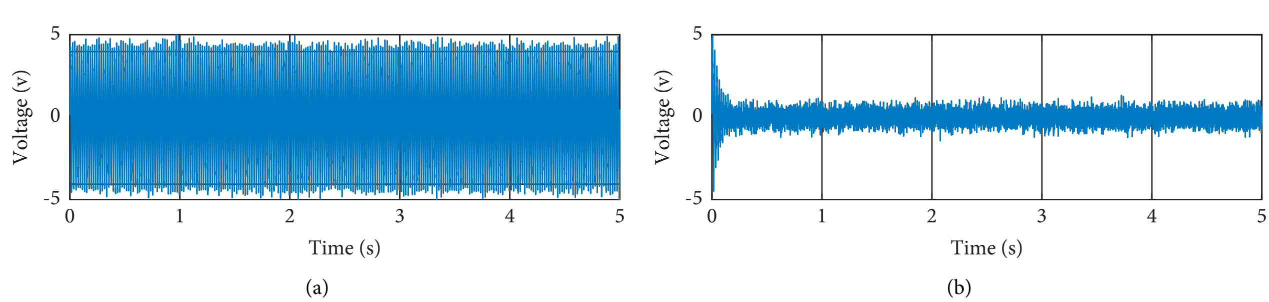

Figure 20: Comparison of (a) ANC-OFF and (b) ANC-ON.

Table 4: Performance comparison.

Method	Comparison parameters			
	Maximum step size	Number of iterations	Noise cancellation effect (dB)	Convergence time (ms)
Proposed	0.042	41	17.2	4.05
AVSS-LMS	0.015	70	16.0	5.91
Salman	0.01	220	15.5	18.21
FXLMS	0.01	413	14.3	22.3
Piecewise	0.03	55	14.9	4.25

experimental results that the improved method has a more satisfactory effect on the regular noise cancellation, while there is still some room for improvement for random noise.

In Table 4, we compare the maximum step size that can be achieved by the five algorithms, the number of iterations when $MSE \leq 0.1$, and the noise cancellation effect when applied to pipelines. The test environment for the five algorithms is consistent with the test signal. The proposed, AVSS-LMS, piecewise, fixed-step FXLMS, and Salman algorithms take 0.9901, 0.9438, 0.7719, 0.5406, and 0.8281 s, respectively, to perform 10000 iterations. In Table 4, the convergence time is the product of the average single-step iteration time and the number of iterations. Although the total time for the proposed algorithm to complete $n = 10{,}000$ iterations is the longest, it takes only a few iterations to converge, so the time for the proposed algorithm that converges to $MSE \leq 0.1$ is shorter than that of the other four algorithms. It can be seen that the maximum step size that can be obtained by the proposed method is larger compared to the other four algorithms, and therefore, the number of iterations is relatively less. In addition, the comparison in Table 4 also provides that the improved method can reduce more noise than the remaining four methods, and AVSS-LMS also has a better noise cancellation effect. The piecewise method is influenced by the segmentation strategy, and the segmentation points need to be retested after the usage environment has changed.

The proposed algorithm can quickly eliminate noise in pipelines. It has good tracking performance for rotation noise. The piecewise LMS algorithm can also converge rapidly for pipeline noise, and at the beginning of the iteration, it can achieve convergence performance close to that of the proposed algorithm (Figure 18). However, Figure 19 shows that MSE of the piecewise LMS algorithm is significantly higher than that of the proposed algorithm at a stable state, which is attributed to the nonsmooth change in the step size of the piecewise LMS algorithm at a steady condition.

Based on these results, compared with the other four algorithms, the proposed algorithm has a better suppression effect on rotation noise generated by the axial fan in HVAC pipelines. The algorithm uses the arctangent function to nonlinear the error signal and step size. In the effective noise reduction area, the random noise can be reduced by 12–17 dB, and the noise is reduced by about 83%–92%. Experiments and simulations show that the proposed algorithm has advantages in terms of convergence speed, steady-state error, and noise cancellation effect, and its comprehensive performance is better than that of the other four algorithms.

7. Conclusion

This study proposes a new variable step size FXLMS algorithm for ANC systems in HVAC pipelines. We present a variable step size FXLMS method based on the arctangent function based on in-depth evaluations of Neil, Wang, and Salman's step size modification strategies. The algorithm uses the boundedness and continuity of the arctangent function to nonlinearly transform the error signal, so that the step size can be adjusted following the change in the error signal, compared with the mainstream ANC algorithms that significantly improved convergence speed. It reduces the noise generated by the axial flow fan in HVAC systems and has a good noise cancellation effect. The proposed algorithm has an excellent response on standard PVC pipelines, but the algorithm may not converge for nonstandard pipelines due to the mismatch of the air pipeline SP. As a result, the algorithm may not converge when used for nonstandard PVC pipelines. A further research task in the future is to investigate how to provide a more accurate SP model for the algorithm, so that our proposed algorithm can be easily used in various types of HVAC systems.

Abbreviations

ANC: Active noise control
HVAC: Heating, ventilation, and air-conditioning
VSS-LMS: Variable step size least mean square
FXLMS: Filtered-X least mean square
MSE: Mean square error
SP: Secondary path
SVS-LMS: Sigmoid variable step size LMS
AVSS-LMS: Antiinterference variable step size LMS
TVOCs: Total volatile organic compounds
PVC: Polyvinyl chloride
SNR: Signal noise ratio.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

A Theoretical Analysis of the Effectiveness of Sports Flipped Class Teaching Based on Motor Skill Learning

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This article compares the characteristics and advantages of flipped sports classrooms with other disciplines and traditional sports classrooms, and analyzes the characteristics and advantages of flipped sports classrooms, using the method of experimental comparison and comparative analysis to sort out the characteristics of Flipped classes in the application of teaching practice. Adjusting the teaching process and structure, with sports skill teaching as the main line, can create conditions for the deepening and expansion of PE. Students are the main body in a flipped class, which confirms the teaching concept. With the advent of the Internet era, students can access the information network at any time and from any location to gain PE knowledge. To meet students' learning needs, teachers must interact with them more and grasp teaching feedback more quickly. To sort out and research flipped classroom teaching in physical education, compare the use of flipped classroom teaching in physical education to traditional PE teaching over time, and demonstrate that flipped classroom teaching in physical education should be based on sports skills teaching and the teaching process. Making the necessary adjustments can help students learn in a positive environment. Then it examines two levels of technology and operation implementation in order to provide theoretical support for Flipped classroom teaching and improve student learning efficiency.

1. Introduction

Due to the ever-increasing use of the Internet, the educational model has undergone significant changes [1]. Flipped classrooms are becoming more common as the Internet era progresses. Using information technology in the classroom can help improve teaching efficiency and promote educational reform. Physical education (PE) is an important part of college and university education, as it promotes students' physical and mental health. The use of Flipped classes in college and university PE can be beneficial [2, 3].

Physical education (PE) classes are becoming more templated in today's colleges and universities [4]. PE teachers plan all of their lessons meticulously, no matter where they are in the process. Students are doing teacher-directed preparation activities, learning physical skills, and not having enough room in their PE class for self-expression. [5] Inflexible and mechanical, with no room for play. If things keep going this way, things will only get worse. PE teachers use this teaching model to instill physical skills, create various training activities to help students improve their sports skills, and exaggerate students' athletic abilities [6]. This teaching model fails to effectively cultivate students' athletic and humanistic qualities, which has a negative impact on their personal development [7].

Teachers must test the theory in the real world to ensure that flipped sports classrooms are as effective as they claim to be. It is hoped that this study will encourage the use of flipped classroom teaching methods in physical education, thereby speeding up the reform of the subject [8].

2. Related Work

As a result of its widespread use in the classroom, it has evolved into a new teaching method that is in opposition to traditional teaching theories. Is it possible to describe a flipped class?

The Flipped Class education model was created by Jonathan Berman and Aaron Sams, two chemistry teachers at Rocky Mountain Woodland Park High School in Colorado, USA [9].

Flipped classes, according to the literature [10], are a method for increasing interactive and individualized contact time between teachers and students; they are a personalised teaching environment in which students can receive individualized education. The teacher is no longer the dictator on the podium, but the instructor of the students' learning; the teaching content is saved, and students can review it at any time based on their own circumstances; the teacher is no longer the dictator on the podium, but the instructor of the students' learning; the teaching content is saved, and students can review it at any time based on their own circumstances. It's a teaching method that combines direct explanation with constructivist learning to prevent students from falling behind in class.

Literature [11] believes that the role of teachers and students in traditional classroom teaching has been rearranged as a result of the Flipped Class, and that classroom time is better utilized by reversing the knowledge transfer and internalization arrangements.

To complete the knowledge transfer and enter the stage of knowledge internalization in a Flipped classroom, the literature [12] believes that knowledge transfer before class must exceed the teaching effect of teacher instillation. Students will not be able to do their best outside of the classroom if they do not do their best in class. To put it another way, the success of a lesson can be measured by the extent to which the students' prior learning has influenced the teacher's teaching in a traditional classroom and the students have fully internalized the course's content.

According to literature [13], students learn independently before class using teacher-created materials, then participate in teacher-student interaction activities and complete exercises in the classroom. [14].

According to literature [14], flipped classes involve teachers creating instructional videos that students watch at home or outside of class before returning to class to share their learning outcomes and experiences face-to-face.

The flipped classroom teaching model is a traditional teaching model in which students complete homework assignments at home, allowing them to learn at their own pace and in their own time, and the classroom becomes a place where teachers and students interact, promoting knowledge internalization through strategies such as solving doubts. [15] Literature.

According to Literature [16], flipped classrooms are located in an information-rich environment. Teachers use instructional videos as a primary mode of instruction for their students. Students watch and learn from videos before class. For both students and teachers, classes are a time for teaching and learning. Active communication and other forms of engagement are incorporated into a new approach to teaching and learning.

According to literature [17], a flipped class is an educational method that improves knowledge transfer and ability to retain it. As a result, he thinks Flipped Class should be renamed Flipped Teaching, because the relationship between teachers and students has fundamentally changed.

To summarize, this article's definition of flipped class is: Using information technology and network resource management as a platform, the teacher provides learning for students in class by creating teaching videos that allow students to complete knowledge learning before class and achieve the desired results. Exchange opportunities, assist students in internalizing knowledge, and create a new type of teaching model for students to become true masters of learning.

3. Analysis of the Characteristics of Flipped Class

3.1. Teaching Presupposition from Rigid Presupposition to Flexible Presupposition. The concept of Flipped class has more characteristics than the traditional classroom teaching mode, and it is also derived from the traditional classroom concept, and its characteristics are more prominent than the former [18].

In traditional classroom teaching, teachers have always held a dominant position in education, and students have always been in a passive learning state. In the Flipped Class Teaching model, the role attribute of classroom teaching is reversed. In the classroom, the student takes on the role of protagonist, while the teacher takes on the role of organizer.

Teachers in traditional classrooms have a tendency to meticulously design the curriculum, step by step, and gradually advance the pre-set mode [19]. The interlocking instructional design will not be able to move forward as long as the teacher decides what students are allowed to express. As a result, students are frequently given teachers' teaching tasks, and students lose more autonomy and critical thinking skills, as well as their enthusiasm for the classroom.

3.2. The Teaching Process Is Reversed from First Teaching and Then Learning to First Learning and Then Teaching. Teachers have traditionally imparted new knowledge to students in the classroom, while students work to retain it outside of class time. Internalization, on the other hand, is more challenging for students. The flipped classroom model can be fully integrated into student learning when used in the classroom. The use of a flipped classroom causes traditional teaching methods to be disrupted. It goes from teaching first and then educating to learning first and then educating, as shown in Figure 1.

Students use the network platform's resources to gain a basic understanding and knowledge of new information during their free time. Rather than teaching new information, the teacher uses class time to guide and explore students' previous learning problems. Internalization can then be enhanced, allowing students to gradually master higher-level knowledge [20].

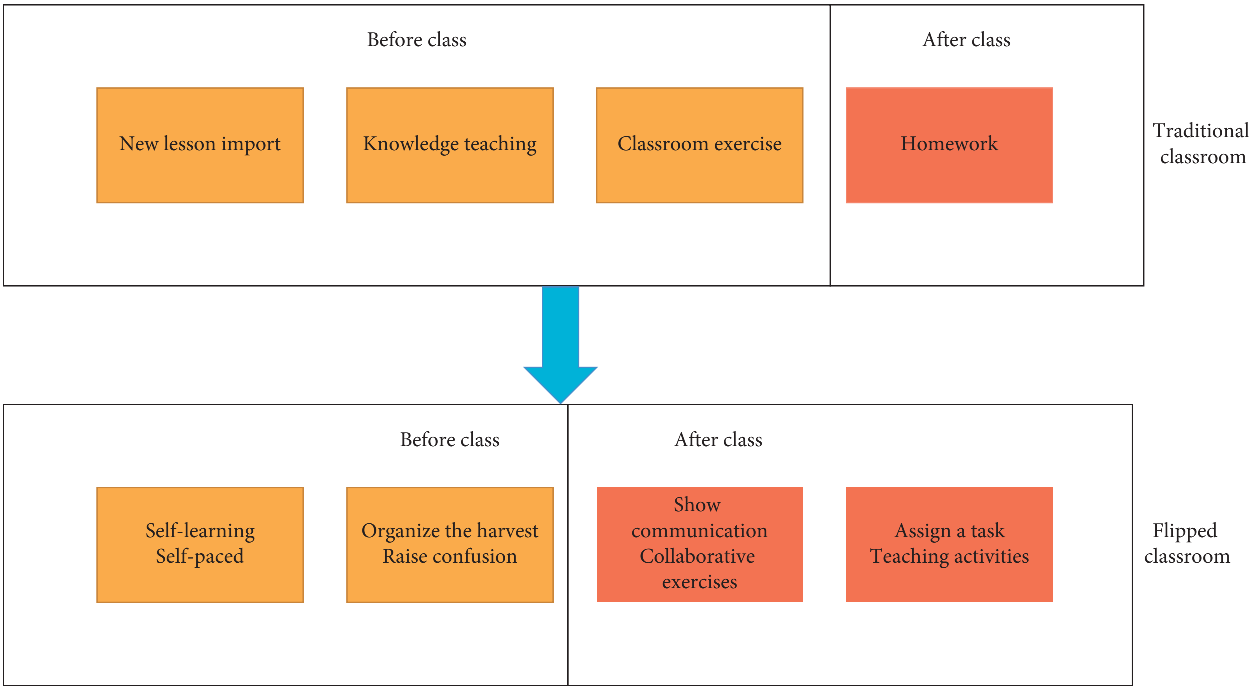

Figure 1: Process flip from traditional teaching to Flipped class.

3.3. Students' Learning Mentality Changes from Passive Acceptance to Active Exploration. In a traditional classroom, the teacher's lecture hall is the classroom. The students' task is to learn one line passively. Listening to the lesson and taking notes has become a routine for the students, and it is easy for them to lose interest in learning classroom knowledge. Flipped classrooms, as opposed to traditional classrooms, allow students to learn more actively, internalize concepts in class, and integrate them into their own cognitive structure. Students in the Flipped class spend more time in class discussing their own problems, interests, depth, value, and other issues in groups and with teachers, enhancing the value of classroom teaching and enabling each student to meet their own needs and increase interest, thereby enhancing the significance of Flipped class education in many ways.

4. Necessary Conditions for the Implementation of Flipped Class

4.1. Schools Must Have a Supporting Environment for Flipped Class. It is clear that information technology [21, 22] plays a critical role in implementing Flipped classes in the classroom; without it, Flipped classes will not be implemented. To some extent, information technology advancement is a precondition for using Flipped classes, and Flipped classes can only be presented with the help of highly developed information technology. As a result, since its inception in the nineteenth century, the Flipped class has only evolved [23]. This flipped teaching mode allows for self-study outside of class and classroom teaching after class. Technology is inextricably linked to any link, such as video production and transmission of teaching content, students watching video learning, and teacher-to-student individual communication. It is impossible to comprehend the situation and teach students according to their abilities without the use of information technology. A large classroom with cutting-edge technology is required for this flipped teaching mode.

The above-mentioned large environment of advanced information technology consists primarily of two major systems: hardware and software. Figure 2 depicts the four aspects of the hardware system:

4.2. The Overall Design of the School Curriculum. Flipped class implementation necessitates a thorough review of all courses offered at the school; otherwise, a slew of unfavorable implementation issues will arise. If each teacher makes partial or overall changes to the curriculum based on his or her own preferences, it will result in duplication of teaching content. Missed classes, subject confusion, and lengthy homework assignments after class are just a few of the issues. To avoid conflicts between courses, subjects, and time, general rules for overall design should be followed before implementing Flipped classes [24].

4.3. School Teachers' Teaching Ability Requirements. Before implementing a Flipped classroom, it is critical to address the issue of teachers' ability to use technology. Teachers in Flipped Classrooms should receive technical training from their schools. Teachers are the only ones who have truly mastered the use of information technology in education. With the help of network platforms, flipped classrooms can be implemented more efficiently [25].

Teachers' abilities are improving, so flipped classrooms cannot be ignored. To meet this demand, teachers of

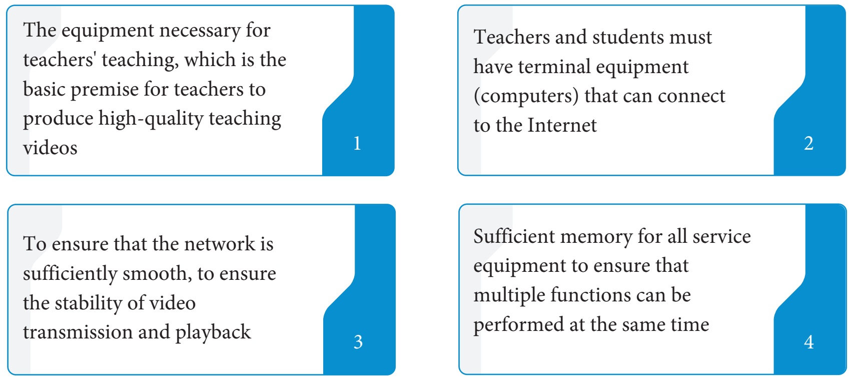

Figure 2: The Flipped class hardware system covers four aspects.

physical education (PE) must meet higher standards. Because it differs so much from other academic disciplines, physical education (PE) instruction can be difficult to implement. Because there are so many students, PE teachers find it difficult to know when to use Flipped classes. PE teachers can make an informed decision based on their ability to manage a PE classroom and their extensive teaching experience. As a result, schools should focus on cultivating PE teachers' ability to teach in a variety of modes, including traditional indoor and outdoor teaching, as well as the Flipped classroom. Each method of instruction has its own set of benefits and drawbacks. They do not have a positive or negative aspect to them. Appropriate or inappropriate is the only way to tell them apart. In order to achieve the best learning effect, PE teachers should adjust measures to local conditions and time, according to specific teaching content, and the actual situation of students chooses the best teaching mode [26].

5. Feasibility Analysis of Sports Flipped Class Teaching Based on Sports Skill Learning

5.1. Acknowledgement of the Help of Flipped Class for Sports Learning. In a flipped class, students move from a traditional templated classroom to an autonomous-mutual aid classroom based on motor skills [27]. During this transition, students must move from passively imitating actions and passively following instructions to active learning [28]. As a result of the transformation of inquiry, communication, and learning, students must have the ability and awareness to learn sports skills independently, actively participate in teaching, and effectively interact with teachers. Through questionnaires, seminars, and other means, this paper investigates the role of sports skills on students' learning and independent learning of sports in six elective PE classes in a college class to assist in the teaching of sports skills, a total of 377 students, 195 boys and 182 girls. The state of one's motor skills is examined.

Sports skills can benefit students in the form of self-paced learning before class, repeated observation after class to consolidate technical movements, and new ideas in movement arrangement in class. Figure 3 shows how students can learn sports skills by using open feedback.

As the Internet era and new learning methods have emerged, students' desire for sports resources has grown. Learning nowadays takes place outside of the classroom. When students have access to high-quality sports skills resources, they are more enthusiastic about sports. Learning physical education necessitates the acquisition of a wide range of abilities.

5.2. Investigation on the Flipped Class Consciousness of Autonomous Learning PE. The questionnaire survey is shown in Figure 4:

189 students prefer to study before class, especially if the number of views increases the day before class. After class, 135 students are still choosing to review. The majority of these students, according to interviews, are accustomed to the teacher's intuitive teaching in class, imitate the teacher, and spend less time reviewing after class. 57 students combined pre-class and post-class review. There are students who enjoy the course in particular, as well as students who lack coordination. Only a small percentage of students who prepare before class have poor self-study quality, according to survey and interview findings. Furthermore, many students continue to rely on their teachers' classroom instruction and do not take the initiative to do pre-class video learning, resulting in them remaining in class. Teachers and students are unable to communicate effectively with one another.

5.3. The Teaching Concept of PE Teachers Needs to be Updated. Thanks to technological advancements, PE reform in colleges and universities has gotten a big boost. Some PE teachers, who are eager to try out new ideas and methods, have embraced the use of information technology in PE. While this is a step forward, some PE teachers in traditional colleges and universities are still stuck teaching and improving sports skills as a coaching method. The teacher-student relationship is marked by an unwillingness to study students' learning methods in depth and a lack of understanding of PE reform, rather than focusing on the development and improvement of students' self-directed learning abilities. The lack of themes and limited communication channels are to blame. It's common to focus on the students'

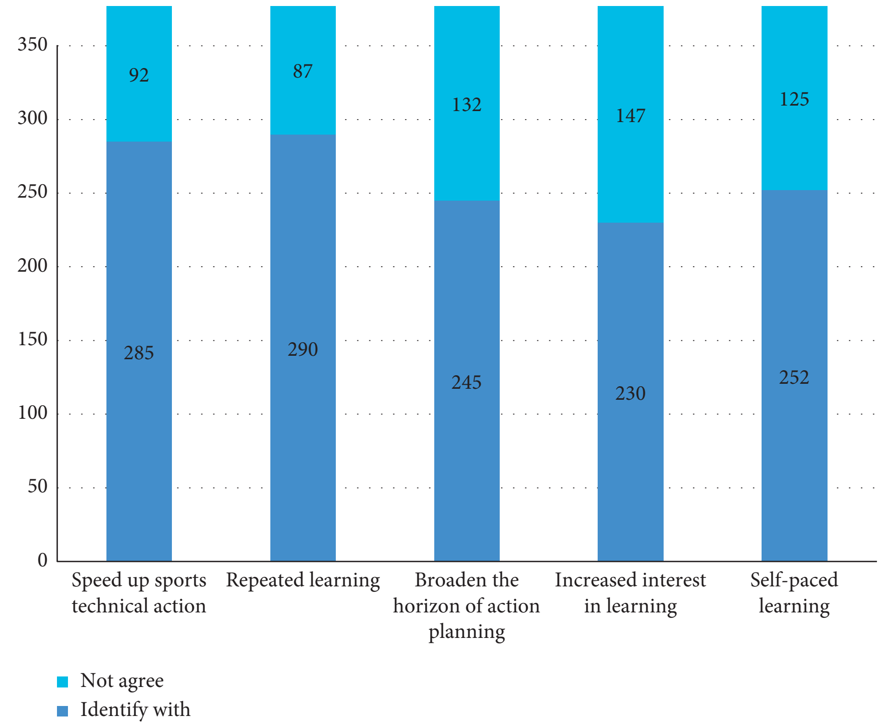

Figure 3: Statistics of Flipped classs for learning aids.

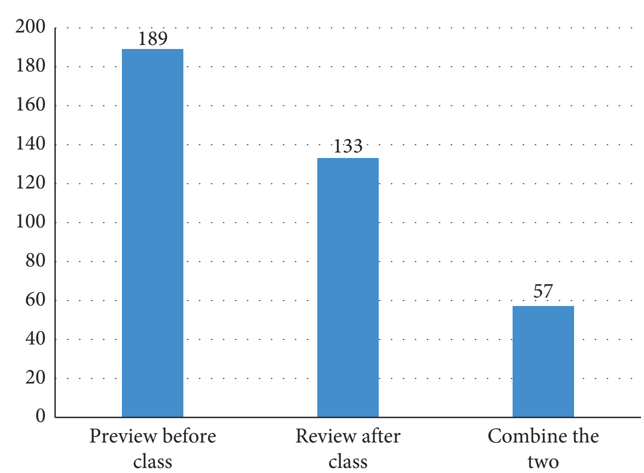

Figure 4: Survey statistics of self-learning sports Flipped class.

outcomes rather than their progress when evaluating their learning.

These sports departments have incorporated modern artificial intelligence [29–31] into their educational resources, making sports-related information more accessible to students, teachers, and the general public. In the field of physical education, the number of master's and doctoral students has steadily increased, as has the academic credentials of PE teachers hired by universities. In a flipped classroom, traditional PE is not taught. It has the potential to energize classrooms, motivate students to participate in sports, and improve the quality of classroom instruction, in addition to increasing student motivation and engagement in physical activity. In order to rely on the promotion of PE, college PE teachers must actively learn and implement the theories of Flipped Classrooms, as well as continually reflect on classroom issues and improve classroom teaching quality. Students' overall development and well-being.

For today's students, mobile phones can be the most direct means of instruction. Students can now access a wealth of sports-related information and video resources via their mobile phones and the Internet, and physical education teachers can use these tools to provide students with self-paced, self-guided learning opportunities. It's all about resource sharing. PE instructors who believe in the practical and interactive nature of the curriculum and are unconcerned about the integration of technology into college PE courses are still in the minority. Flipped PE classes are difficult to develop because it is difficult for PE teachers who are used to a more traditional model of teaching to embrace the use of technology in their classrooms.

6. Analysis on the Effectiveness of Sports Flipped Class Teaching Based on Motor Skill Learning

What is the most effective method for teaching sports skills? To be an effective sports skill teacher, you must first understand what type of instruction is most effective. The term "effective" is used when students make specific progress or development after receiving instruction. To put it another way, the only way to tell if a teacher is effective is to look at their students' progress. Even if it is extremely difficult, teaching is ineffective or inefficient if the student does not want to learn or does not benefit greatly from it. Teachers use their own desire to learn as a starting point to pique students' interest in learning.

When it comes to classroom teaching and sports skill instruction, there are a lot of moving parts. This article uses University A and University B as examples. In A college PE, flipped classes are used, while in B college PE, traditional classes are used. There are 120 target classes, and no significant differences in physical fitness exist between them.

6.1. Comparative Analysis of Student Practice Density. Students in a flipped classroom learn sports knowledge and action methods through the use of micro-videos. In the micro-class learning stage, students begin to learn and practice knowledge and movement. As a result of this, students will be able to learn more about sports and movement methods, free up more time for students to practice activities, and increase the amount of effective practice time that they have available to them. The number of students practicing in the classroom increases. Flipped and traditional classrooms are compared in Table 1 by student practice density.

A reasonable range is shown in Table 1 for the practice density of the two pieces of information. Flipped Class A and traditional classrooms have very different student practice densities. Students in Flipped Class A have a higher practice density than students in traditional classrooms; however, students in Flipped Class B have a lower practice density than students in traditional classrooms. The experimental results show that A outperforms B in terms of autonomous learning ability. Open-motor skills are also more effectively taught using the Flipped Classroom model. A higher density of practice was achieved in traditional lessons as a result of teachers' use of course design methods that were more open to adopting the new curriculum concept than other teachers.

6.2. Comparative Analysis of Students' Practice Intensity. While physical exercise is the primary method for students to improve their overall physical fitness, they are also given more time for exercise, but with a limited amount of time to achieve an appropriate level of exertion. Students in both a traditional classroom and a flipped classroom work hard (heart rate) Table 2 shows the results of the comparative analysis.

Except for the squatting start, there are significant differences in exercise intensity between the Flipped classroom and the traditional classroom. When compared to traditional PE classes, Flipped PE classes require significantly more physical effort.

A passing class in basketball is shown in Figure 5 as an example of a rational analysis of exercise intensity.

The Flipped class's heart rates range from 120 to 150 beats per minute, which is between medium and low intensity and meets the basic requirements of warm-up activities, as evidenced by the gradual increase in heart rate over the first 12 minutes (preparatory activity). In the second half of the 15–36 minute part of the basic requirement, there are two peaks of 192 times/min and 204 times/min, but the duration is short, reflecting the quality exercises in the second half. It's undeniable. The heart rate gradually rises during the first 12 minutes of traditional classroom (preparatory activity), and it is between 126 and 144 beats per minute, which is medium to low intensity. It's finished as part of the warm-up. 15–30 minutes at 150 beats per minute in the first half, then 174 beats per minute in the second half. Despite this, the summit has yet to fall below its peak elevation. As evidenced by the rapid decline in intensity toward the end of the 33–40 minute period, the second half of the quality training arrangement lacked high-intensity quality training. Because the traditional classroom exercise load intensity is lower, students' physical fitness improves significantly when taught in a Flipped classroom.

6.3. Contrastive Analysis of Students' Mastery of Motor Skills. What impact will the flipped classroom have on motor skill acquisition? As shown in Table 3 of this article, two groups of experts, A and B, observe the students' on-the-spot mastery of motor skills and then grade them using a scale.

Micro-classes in the classroom teaching process and the organizational effects of the classroom are one of the most important factors that determine the level of skill mastery, especially for team Learning content with a lot of collaborative elements, as shown in a flipped class with strong team cooperation.

Unlike traditional teaching, flipped class teaching generates enthusiasm for sports participation, a reasonable amount of physical activity, and effective motor skill learning. Students' physical health and fitness have improved as a result of the Flipped classroom. In flipped classrooms, students are more encouraged to express themselves than in traditional classrooms. Through goal-led and task-driven micro-class and classroom learning, students are encouraged to actively participate in learning activities, deepen their autonomy, cooperation, and inquiry, and effectively change how they learn. Thanks to the flipped classroom, teaching methods are fundamentally altered, teachers create student-centered activities, and the concept of teaching for learning is realized. The ability to innovate has been significantly enhanced.

Table 1: Comparison of student practice density between Flipped class and traditional classroom.

Subject	Flipped class		Traditional classroom		t	P
	n1	Proportion/%	n2	Proportion/%		
Basketball pass	46	75	45	51	2.367	<0.05
Squat start	49	79	47	39	3.966	<0.01
4 × 50 m Relay	40	72	42	60	1.178	>0.05
Aerobics	44	73	43	59	1.342	>0.05

Table 2: Comparative analysis of student practice intensity between Flipped classs and traditional classrooms.

Subject	Flipped class		Traditional classroom		t	P
	Average heart rate X1	S1	Average heart rate X2	S2		
Basketball pass	135.31	19.01	126.50	18.85	2.427	<0.01
Squat start	123.63	17.11	119.56	16.32	1.284	>0.05
4 × 50 m Relay	145.51	30.24	130.53	23.52	2.992	<0.01
Aerobics	138.12	27.35	125.51	19.25	2.492	<0.01

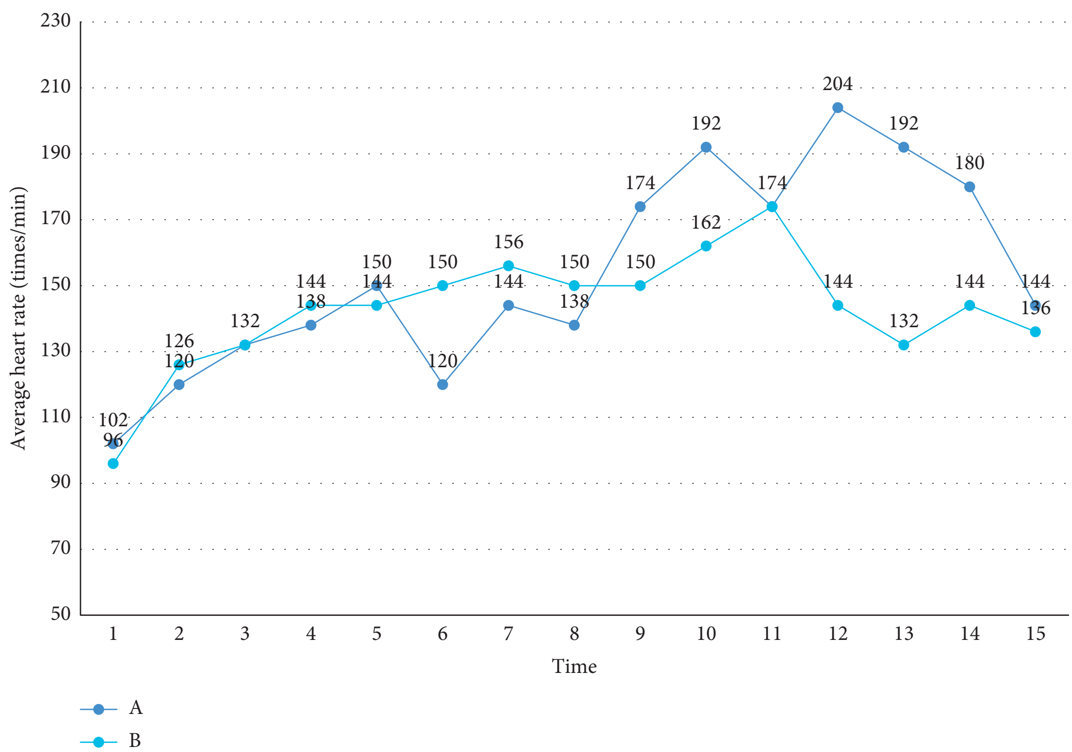

Figure 5: Comparison of heart rate curves between Basketball pass Flipped class and traditional classroom.

Table 3: Comparative analysis of students' motor skills mastery in Flipped classs and traditional classrooms.

Subject	Flipped class Average mastery score	Traditional classroom Average mastery score	t	P
Basketball pass	92	62	3.420	<0.01
Squat start	86	74	1.517	>0.05
4 × 50 m Relay	88	74	4.456	<0.01
Aerobics	53	51	0.259	>0.05

7. Conclusions

The popularity of flipped classroom teaching has grown as a result of the widespread use of multimedia technology. In order to stay on schedule, the college PE curriculum must be flipped to compensate for the information, content, and conceptual gaps. Maintain a steady pace with your field's current trends. The introduction of the flipped classroom teaching concept, which can serve as a supplement to, promotion of, and challenge to traditional university PE classroom teaching, could greatly benefit my country's colleges and universities. Some of the advantages of this method of teaching in college PE classrooms include a panoramic view of the content of PE courses, the development of sports interests and hobbies, and the establishment of good physical exercise habits. Traditional teaching methods and concepts have been reshaped by flipped classrooms for many teachers. Students and teachers are able to interact more frequently in a flipped classroom, resulting in a better value and emotional system for the students. In order to achieve a comprehensive assessment of students, we should evaluate their learning outcomes as well as their learning process using a comprehensive, multi-angle, and three-dimensional evaluation method.

Traditional teaching models influence Flipped class instruction; the network teaching environment is imperfect; there is a lack of relevant theoretical research and practical experience in sports practice Flipped classes; teachers lack production teaching resources and the ability to use micro-video; and students lack self-learning abilities.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author does not have any possible conflicts of interest.

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Research Article

Research on Energy-Saving Design Method of Green Building Based on BIM Technology

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In view of the shortcomings of the traditional architectural design mode, such as high rework rate in the construction process and lack of collaborative design and intelligent information processing, a green building energy-saving design method based on BIM technology was proposed. Based on the comparative analysis of traditional computer-aided building design and BIM green building technology, the overall scheme of energy-saving design was constructed from the aspects of green building design principle, design preparation, and design concept. This paper expounded the connotation of energy-saving design elements from the aspects of modeling software selection, envelope energy-saving design, and lighting energy-saving design. Accordingly, the characteristics and process of building energy efficiency analysis based on BIM were proposed. Finally, the energy-saving effect evaluation method of green building based on BIM was given, and an example showed that the energy-saving design method of green building based on BIM proposed in this paper had good feasibility and effectiveness. The method proposed in this paper can provide a certain theoretical basis and application support for the application of BIM technology in the field of green building.

1. Introduction

Since the end of the last century, most developed countries have been deeply exploring green buildings and their applications and have successively issued some different evaluation standards based on the reality of various countries, which has accelerated the development of green buildings in the world to a great extent [1–3]. With the continuous development of green building field, BIM technology has been widely used in western developed countries. Relevant personnel in other countries have also conducted relevant in-depth research on BIM theoretical and technical system and its practical application and made great progress. Some scholars can realize the simulation of building energy-saving design and its effect by combining a three-dimensional building model with energy consumption analysis.

In recent years, with the promotion of BIM software, such as Revit series of Autodesk company and ArchiCAD of graph iSOFT company, it has been well applied in the field of green building [4, 5]. Applying BIM technology to the design of construction projects can not only predict and find the deficiencies in the design but also avoid the additional consumption in the actual construction process [6–8]. For example, the effective integration of building a 3D model and structural model with the Revit structure can promote the information exchange and collaborative work of construction project participants.

The application of BIM technology is conducive to the completion of various design, construction, and later maintenance of construction projects, which not only promotes the renewal of architectural design methods but also improves work efficiency [9, 10]. With the global energy crisis, energy shortage, and the continuous deterioration of the natural environment in recent years, how to use BIM technology to carry out energy-saving design of green buildings and scientifically evaluate the energy-saving effect has become a concern of relevant scholars. However, there are still some deficiencies in the application of BIM technology in green buildings, such as insufficient design accuracy and unscientific intelligent processing method. Therefore, how to improve green building design based on BIM technology is one of the urgent problems to be solved in the field of green buildings.

2. Related Works

Developed countries are the first to use BIM technology and have applied it to the whole process of construction projects. With the deepening of the concept of building energy conservation, the research and application of green building are also developing. Technology provides strong support for promoting the development of the construction field [11–13]. The adopted building information model can visually reproduce the real scene of the building and its stages from different dimensions, which fundamentally overcomes the shortcomings of the traditional building model. The core software of BIM can parameterize the building model and predict or simulate various situations that may occur in the building process through various information contained in the model. The collaborative operation between BIM building information model and other types of energy-saving analysis software can scientifically evaluate the design effect of green buildings.

Using the traditional computer-aided design mode, due to the decentralized management of various departments and the inconvenient communication of information, it is difficult to realize the collaborative requirements of all parties in the construction project. The green building based on BIM technology not only maintains information interaction but also can use the collaborative work platform to carry out effective information interaction and integrated management for all personnel involved in the construction [14, 15]. It provides important technical support for the collaborative development of the construction industry and other fields. The comparison between traditional computer-aided building method and BIM green building technology is shown in Table 1.

The core of BIM can not only use BIM technology to optimize various architectural designs but also optimize the cooperation mode of partners in different stages of the construction process to effectively save the comprehensive cost of the building and reduce the energy consumption of the building. In addition, BIM technology is used to simulate building energy consumption. Based on the analysis of the simulation results, the building design scheme is continuously optimized, the best scheme is selected, and the resource utilization rate is also improved.

BIM technology has changed the design mode in the sense of traditional architecture. BIM building model can not only visualize space facilities but also extract relevant data and information by using the model, which is conducive to the design, construction, and maintenance of green building projects and can meet the communication and decision-making of construction projects by participants in different stages [16, 17]. In addition, the data platform provided by BIM can provide information support for effectively formulating various construction-related work plans such as construction cost plan, material use plan, and personnel scheduling plan to avoid risks, reduce costs, and improve efficiency during the implementation of construction projects.

The traditional architectural drawing cannot integrate information, and it is difficult to communicate during construction. Because the drawings and information of traditional building models are generally not related to each other, model modification is not only time-consuming but also prone to errors, which is difficult to provide substantive help for the construction industry building model that can predict the real situation after the completion of the building through information interaction, and BIM data center can provide various data for different stages and provide relevant services after the completion of the building. Participants in different stages of project implementation can update information synchronously without checking architectural design and construction drawings. As shown in Figure 1, the comparison results between the traditional building model and the BIM building model are shown.

3. Overall Scheme of Energy-Saving Design

3.1. Principles of Green Building Design. In the whole process of green building, energy-saving design not only is related to architectural features but also considers natural environmental factors and the relationship between the external environment and architectural features. Therefore, green building design needs certain principles.

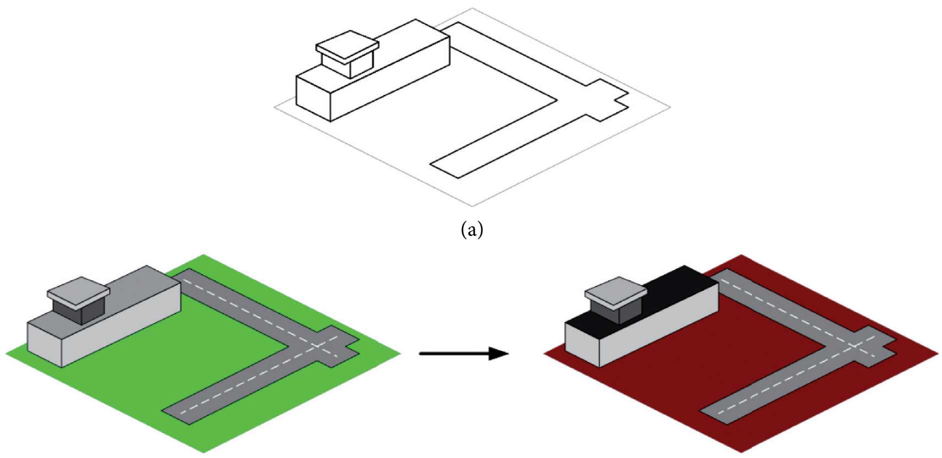
(1) We should adhere to the principles of sustainable development and people-oriented. In order to meet the needs of long-term and stable development, green buildings should be able to coordinate the problems of sustainable development such as resource consumption, environmental pollution, and resource conservation. Because the building energy-saving design is to better transform human living space, on the premise of ensuring that it does not affect the health of residents, the construction equipment and materials should be used reasonably when implementing green buildings.

(2) The energy-saving design of green buildings should comply with the comfort of living and the rationality of technology. When implementing green buildings, we should not only consider the spatial structure needs of residents for housing buildings but also make full use of the solar energy, wind energy, and other resource conditions provided by external nature according to the technical standards. Good energy-saving design can provide residents with good indoor temperature, humidity, and other environmental conditions.

(3) Based on the principle of saving resources and energy, the environmental differences in different regions should be considered in the energy-saving design of green buildings. Combined with the characteristics of external natural environment,

Table 1: Comparison between traditional computer-aided architectural design and BIM green building technology.

Item	Traditional architectural design	BIM green building technology
Work cycle	Design phase	Entire cycle
Design dimension	Two-dimensional design	Space design above 3D
Working mode	Independent operation	Collaborative work
Design effect display	Plan drawing	Visual model



(a)

(b)

Figure 1: Comparison between traditional building model and BIM building model.

regional characteristics, and people's social life customs, green buildings should not only conform to the local construction style but also make full use of local resources and environment.

3.2. Preliminary Design Preparation. Since the effect of the energy-saving design is an important part of green building evaluation, whether energy is effectively saved and utilized is an important reference standard, and it is very important to promote the application of BIM in green buildings. In order to ensure the normal implementation of green buildings, the BIM model is generally used to analyze the natural light radiation and distribution outside the building, establish a feasible solar energy utilization scheme, and realize the full utilization of solar energy resources by green buildings.

At the same time, according to the analysis results of indoor natural lighting based on the BIM model, make full use of external lighting to reduce the energy consumption of indoor lighting. In addition, in the selection and use of energy-saving materials, according to the functional requirements of public buildings and the technical rationality requirements of architectural design, BIM technology should be used to detect the electromechanical pipe network to avoid some problems caused by the unreasonable design of electromechanical pipe network. Finally, in terms of indoor environment and structural thermal performance test, the parameters of peripheral structure and thermal function are used as the input parameters of the BIM building model, and the required parameters are calculated through relevant software to ensure that the green building can meet the national standards. If the design or implementation of the construction project does not meet the requirements of relevant national green building standards, it is necessary to reanalyze and calculate the building energy consumption.

3.3. Conceptual Design. In the energy-saving design of green buildings, it is usually transformed into a description that can be implemented according to the construction needs or ideas of residents. Therefore, the relevant design documents are the basis for the implementation of energy-saving of green buildings. When evaluating the results of green building, it is necessary to integrate the relevant building information in the design stage to obtain accurate and detailed energy-saving design information of green building and then import the relevant information into the BIM platform database to provide shared data for all participants in the implementation process [14].

The whole process of implementing green building requires cooperation and collaborative design in different professional fields, and the BIM model can provide a better information management platform for collaborative operation. Because the BIM model includes various detailed information about green building concept, it can provide a basis and support for the simulation and analysis of green building energy efficiency. In addition, the parameterization and modularization of the BIM model can provide accurate information feedback for the later energy-saving design effect. The specific implementation route of BIM-based green building energy efficiency design is shown in Figure 2.

4. Key Points of Energy-Saving Design

4.1. Modeling Software Selection. Green building has been widely used with the development of BIM software technology. Choosing an appropriate BIM software is very important for green building energy-saving designers [18]. A building model is established by using BIM technology. On this basis, the energy conservation of green buildings is designed, the energy consumption is simulated and analyzed, and the technical route of building energy conservation simulation design is formulated according to the simulation analysis results.

In recent years, designers have mostly used Ecotec, Energy Plus, and other types of simulation analysis software to design green buildings and analyze the model simulation results, which has achieved good results. For example, Ecotec software has the characteristics of simple operation and specific analysis. It can optimize relevant parameters according to different architectural design models, providing an effective guarantee for specific implementation. At present, most designers combine the relevant simulation software provided by different BIM model software with Ecotec simulation software, then analyze the data of architectural design models in different stages according to the simulation software in BIM model software, and optimize the energy conservation and emission reduction scheme by using the analysis and design simulation results.

4.2. Enclosure Energy-Saving Design. The roof department of green building needs to be designed with comprehensive consideration of energy-saving factors. At present, the common roof shapes are mainly designed in the styles of high flat roof, slope flat roof, and various streamlined flat roofs. In terms of energy conservation and thermal performance design, it is usually necessary to consider the use of decorative materials, slope design, and thermal insulation layer to achieve good thermal insulation effects in summer and winter.

As the main part of the building, the goal of exterior wall energy conservation is to ensure the appropriate indoor temperature, avoid the impact of external high temperature, and reduce the adverse impact of indoor and outdoor temperature difference. The materials used for energy-saving exterior walls are usually composite building wall raw materials with good energy-saving effects, such as waterproof clay solid brick and centralized thermal insulation wall. As an important part of green buildings, windows are mainly used for ventilation, daylighting, and thermal insulation, which have a great impact on the energy consumption of the whole building to a certain extent. Therefore, the window design should not only meet the residential needs of users but also meet the requirements for building energy conservation.

The latest BIM design method can generally meet the needs of heat insulation and energy conservation of high-rise buildings and their auxiliary enclosure facilities. For example, using the BIM building model, different wall and roof building materials can be selected, and relevant parameters can be set to optimize the energy-saving construction scheme.

4.3. Sunshine Energy-Saving Design. How to design the sunshine conditions not only is the key to the energy-saving design of green buildings but also can affect the daylighting effect in the building. Effective use of lighting energy-saving technology can reduce artificial energy consumption. In terms of natural lighting design, it is necessary to make full use of the reflected light generated by external sunlight to supplement indoor lighting, reduce the energy consumption required for indoor artificial lighting, and meet the lighting conditions required for building residence and life.

According to the national laws and policies on the green building industry, when using the Revit architecture model to simulate buildings, you can import the lighting software Ecotec to simulate and comprehensively analyze the indoor lighting, sunshine, and daylighting of buildings. According to the analysis results, you can adjust the structure of the building model or update relevant parameters for the redesign.

According to the technical standards for green building design, the average daylighting coefficient of bedrooms in buildings is related to sunshine conditions. Generally, the average daylighting coefficient of the bedroom is 4.7%. The better the sunshine conditions, the greater the daylighting coefficient. The daylighting coefficient of indoor halls, kitchens, toilets, and other places is generally 1% [18, 19]. Due to the distance from the windows, it is generally difficult for these rooms to obtain a better sunshine environment. In the energy-saving design of green buildings, we should not only meet the standard of indoor daylighting coefficient but also meet the requirements of indoor energy conservation and environmental protection.

5. Analysis Method of Building Energy Efficiency Based on BIM

5.1. Characteristics of Building Energy Efficiency Analysis Based on BIM. In the past, there were many problems in building energy consumption analysis due to the limitation of technical conditions. The traditional building energy consumption analysis is mainly carried out in the construction process. The architectural design drawing cannot be changed, even if the problems found through energy consumption analysis cannot be reworked, resulting in a waste of human and material resources. Therefore, using the building model to analyze the energy consumption in the design stage and obtain the optimal design scheme can effectively improve the later construction efficiency and reduce the construction cost. The traditional energy consumption analysis method usually only analyzes a single factor without comprehensively considering the influence relationship between relevant factors, which makes this energy-saving scheme lack economy and practicability. For example, in the past, only the high-temperature performance of the building envelope was analyzed, or a single lighting

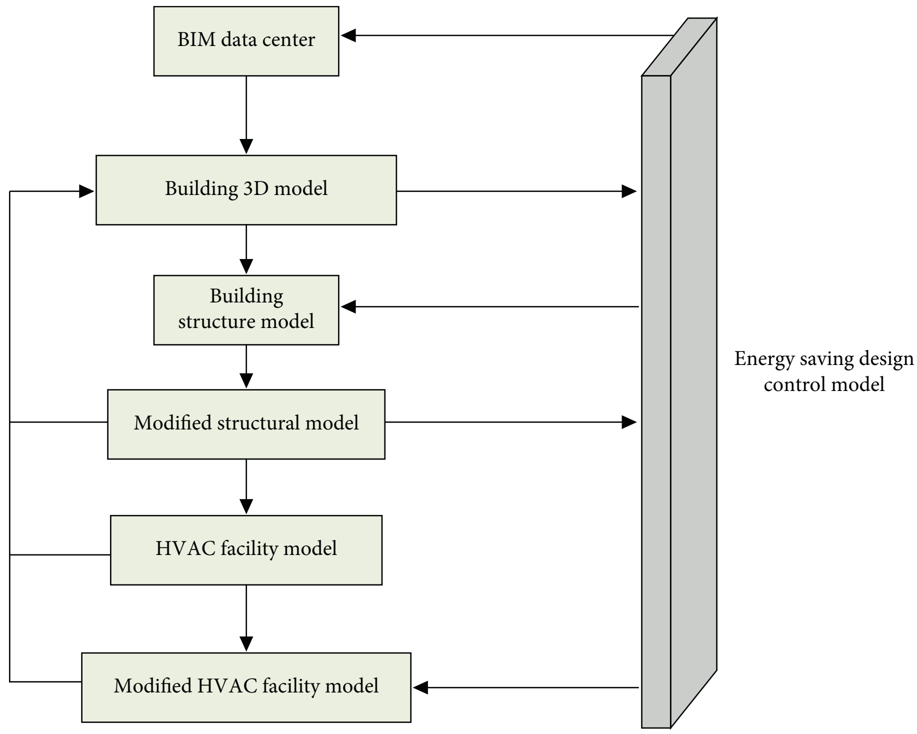


Figure 2: Information transmission process of green building energy efficiency design.

system and HVAC equipment were replaced to realize energy-saving transformation [20].

BIM technology is applied to process and analyze the data, the built building model is used to integrate and analyze the relevant information, external environment, and required parameters, and the building energy consumption is simulated and analyzed by running relevant programs. The building model based on BIM technology can realize the interaction between modeling software and energy consumption simulation software. Because building energy consumption involves the whole and part of the building and needs to be analyzed by using the knowledge of different professional fields, the interaction between different software must be used to help analysts continuously improve the modalism. Technology can realize the collaborative work between parametric modeling and energy consumption analysis, which is not only conducive to the scientific analysis and evaluation of energy-saving design effect but also conducive to the integration and sharing of information in the whole life cycle of the project so as to ensure the management to communicate and manage all departments below. In addition, through comprehensive energy consumption analysis, the building model based on BIM technology can not only analyze individual factors but also evaluate the overall performance of the building and the comprehensive effect of various factors. Thus, it can comprehensively grasp the situation of building energy consumption and provide decision support for various departments.

5.2. Building Energy Efficiency Analysis Process. In recent years, with the rapid development of BIM technology, it is more and more convenient to simulate and analyze building energy consumption, and the application of BIM energy consumption analysis software can comprehensively consider a variety of factors related to building projects in the construction process, such as building energy consumption and indoor energy consumption dynamic analysis. BIM energy consumption simulation software generally adopts Ecotec to design and analyze the energy consumption of specific building projects, and its main process is shown in Figure 3.

Usually, the first mock exam is required for different stages of construction projects. Because the design of a single model is mainly limited to a certain stage, in order to complete the whole construction project, the information of each stage must be integrated and processed. Among them, the interactive operation of each monomer model can not only effectively save the transmission time of information but also avoid various problems due to the required professional differences.

The building model based on BIM mainly contains the overall information of the construction project. Using BIM technology to simulate and analyze the energy consumption can not only export the effective information to the analysis software and complete the relevant analysis but also reduce the repeated work between different stages and improve the work efficiency.

Transfer the information contained in the BIM core building model to the relevant energy consumption analysis software, return the analysis results obtained by the energy consumption analysis software to the building model, and then continuously improve the energy-saving design effect by dynamically adjusting the model parameters. The specific information transfer process is shown in Figure 4.

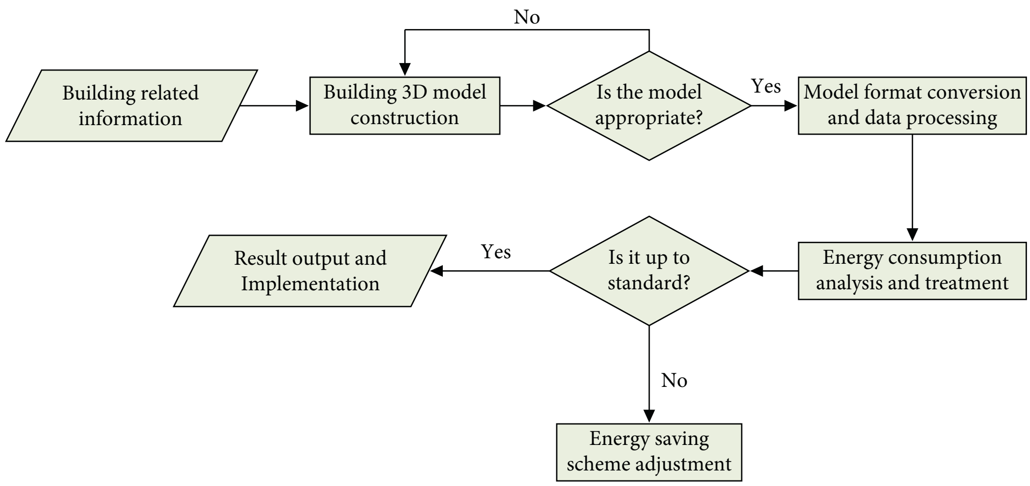


Figure 3: Energy consumption analysis method based on BIM.

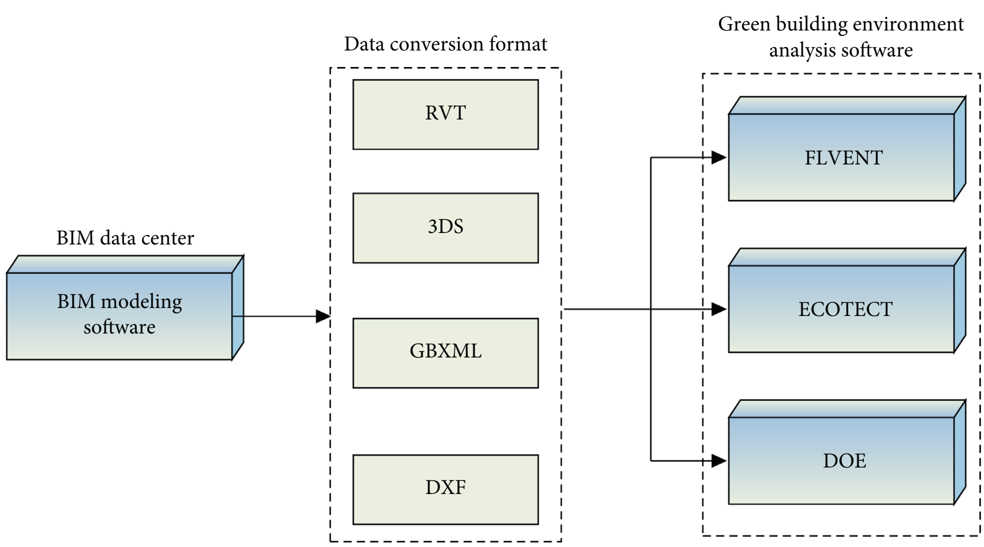


Figure 4: Interaction between BIM core software and building environment analysis software.

6. Energy-Saving Effect Evaluation of Green Buildings Based on BIM

6.1. Construction of Evaluation Index System. The energy consumption analysis software based on BIM technology mainly uses the building model in the design stage to simulate and analyze the energy-saving effect in the construction and use stages. Therefore, it is necessary to establish a relevant evaluation index system to evaluate the energy-saving effect of green buildings. The establishment of green building energy efficiency evaluation index is to promote construction project departments during the construction period; according to the local natural conditions, under the premise of ensuring the safety of the building, effectively improve energy utilization and reduce unnecessary losses caused by construction rework. The evaluation system should not only be the evaluation basis of building energy-saving effect but also provide guidance for guiding green building energy-saving design. Through the evaluation and analysis of the building energy efficiency effect of the evaluation system, the working process of each department of the construction project can be tracked, and the problems existing in the construction project can be summarized and analyzed.

Generally, a good evaluation system needs to follow certain principles. The first is to scientifically evaluate the energy-saving effect of green buildings through qualitative and quantitative analysis methods. Secondly, the evaluation indicators are adjustable and can be adjusted appropriately according to specific construction projects. In addition, it can simplify the index analysis and calculation process so that the evaluation process not only is easy to operate but also gives play to the practicability of the evaluation system.

Based on the evaluation standards of green building energy efficiency at home and abroad, the relevant reports output by green building energy consumption simulation analysis software can basically meet the standards of energy-saving design. Therefore, the simulation results of energy consumption analysis software can be used as the basis for energy-saving effect evaluation. According to the different aspects involved in the energy-saving design of green buildings, the energy-saving evaluation index system of green buildings is established, as shown in Table 2.

6.2. Evaluation Model of Energy-Saving Effect of Green Building. Using the established green building energy efficiency evaluation index system, comprehensively consider the different importance of indicators at all levels in the evaluation system, and calculate the weight value of corresponding indicators. The weight calculation method can consider the principles of subjectivity and objectivity.

According to the objectives, criteria, and specific design scheme of energy-saving design, the hierarchical structure model of the energy-saving effect evaluation index system can be established, as shown in Figure 5.

Based on the above energy-saving evaluation hierarchy model, in order to obtain the weight of each evaluation index, it is necessary to construct a relevant judgment matrix, as shown in the following equation:

$$B = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1m} \\ b_{21} & b_{22} & \cdots & b_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ b_{m1} & b_{m2} & \cdots & b_{mm} \end{bmatrix}. \tag{1}$$

The numbers 1, 2, $\cdots$, 10 are usually used to represent the relative importance of each element in the judgment matrix. Then, according to the evaluation experts, the importance of each index is compared, and the corresponding scores are given to form a judgment matrix.

Then calculate the weight of each index. The specific calculation formula is as follows:

$$\begin{aligned} a_i &= \sqrt{\prod_{j=1}^{m} b_{ij}}, \\ \overline{a_i} &= \frac{a_i}{\sum_{i=1}^{m} a_i}, \\ u &= \sum_{i=1}^{m} \frac{\sum_{j=1}^{m} b_{ij}\overline{a_i}}{m\overline{a_i}} (i = 1, 2, \cdots, m), \end{aligned} \tag{2}$$

where $\overline{a_i}$ represents each component value of the judgment matrix.

$$\begin{aligned} c &= \frac{u - m}{m - 1}, \\ cq &= \frac{c}{q}, \end{aligned} \tag{3}$$

where c denotes the consistency index of judgment matrix, q represents the random consistency index, and cq means the revised consistency ratio.

The random consistency index values are shown in Table 3.

Table 2: Evaluation system of green building energy efficiency design effect and index relationship at all levels.

Item	Primary index	Secondary index
1	Energy-saving design	Feasibility of design scheme Quality of external protection structure Energy consumption
2	Energy consumption	Lighting condition Energy utilization External environmental conditions
3	Daylighting condition	Indoor lighting condition Light transmittance of external window
4	Ventilation condition	Indoor ventilation Indoor air quality Outdoor ventilation

When $cq < 0.1$, it indicates that the judgment matrix has a good consistency. Otherwise, the consistency requirements can be achieved by continuously adjusting the element values of the judgment matrix.

After the establishment of an energy-saving evaluation index system, the qualitative indexes generally need to be treated quantitatively. Therefore, by setting the grade level of each evaluation index and then according to the different levels of these indexes in the evaluation index system or the importance of corresponding projects, they are divided into five grades: excellent, good, medium, qualified, and poor. The above five different grades can be represented by integers 10, 9, 8, 7, and 6 in turn.

The scores of each index are obtained by expert scoring, and the energy-saving effect evaluation sample matrix is established according to the scoring results. For example, suppose that the number of experts participating in the scoring is z, x primary evaluation indicators are scored by experts in turn, and each primary evaluation indicator has y secondary evaluation indicators; then the final energy-saving effect evaluation sample matrix can be expressed as

$$S = \begin{bmatrix} s_{111} & s_{112} & \cdots & s_{11z} \\ s_{121} & s_{122} & \cdots & s_{12z} \\ \vdots & \vdots & \vdots & \vdots \\ s_{xy1} & s_{xy2} & \cdots & s_{xyz} \end{bmatrix}. \tag{4}$$

6.3. Application of Evaluation Model in Engineering Cases. According to the design technical scheme formulated by the Architectural Design Institute, a three-dimensional model of green building is created. Then, based on the BIM platform, different professionals and departments can work together. Figure 6 shows the three-dimensional building model, which includes the building structure model, and Figure 7 represents the electromechanical comprehensive models of building water supply and drainage system, HVAC facilities, and weak current made by different professionals.

Based on the BIM data platform and by importing the building model into the energy consumption analysis software, relevant analysis reports can be generated.

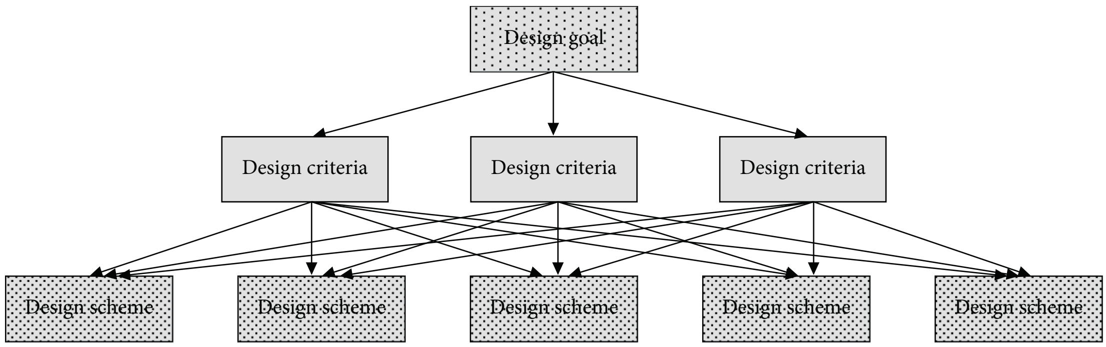


Figure 5: Energy-saving design evaluation hierarchy.

Table 3: Random consistency index values corresponding to different dimensions in the judgment matrix.

Matrix dimension	1	2	3	4	5	6	7	8	9	10
Q	0.01	0.02	0.36	0.54	0.82	1.15	1.27	1.32	1.41	1.49

Figure 6: Three-dimensional building structure model.

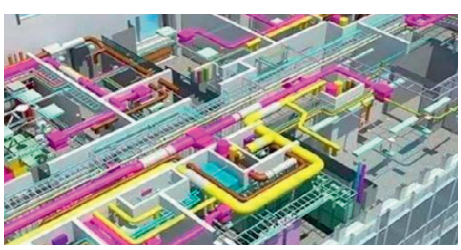


Figure 7: Electromechanical comprehensive model of building water supply and drainage system.

According to the analysis report and the evaluation index system of energy-saving effect of green buildings, the judgment matrix is constructed by using the primary index energy-saving design scheme B_1, energy consumption B_2, daylighting condition B_3, and ventilation condition B_4. The primary index judgment matrix of energy-saving evaluation system is shown in Table 4.

$\overline{a} = (0.136, 0.247, 0.315, 0.063)$ can be calculated from the judgment matrix. According to the consistency test formula, the maximum eigenvalue $u = 4.13$ and $cq = 0.014 < 0.1$. Through the consistency test, the weight values of each primary index are obtained, as shown in Table 5.

Then, each secondary index under each primary index can be compared in turn to determine the judgment matrix of its layer. For example, by judging and comparing various factors under the primary index of energy-saving design, the corresponding judgment matrix is obtained, as shown in Table 6.

Table 4: Primary index judgment matrix of energy-saving evaluation system.

B	B_1	B_2	B_3	B_4
B_1	1	0.5	0.8	1.5
B_2	1.5	1	2.5	3
B_3	0.5	0.5	1	2.5
B_4	0.8	0.5	1.5	1

Table 5: Primary index weight value of energy-saving evaluation index system.

Primary index	Weight value
Energy-saving design	0.136
Energy consumption	0.247
Daylighting condition	0.315
Ventilation condition	0.063

According to the judgment matrix, the corresponding $\overline{a}_1 = (0.124, 0.216, 0.473)$ can be calculated. Through the consistency test, $cq = 0.008 < 0.1$, meeting the requirements. After the consistency test, the weight values of each secondary index under the primary index are obtained, as shown in Table 7.

Similarly, the same method can be used to obtain the judgment matrix formed by comparing the elements under other primary indicators. At the same time, the corresponding weight can be obtained according to the judgment matrix. Finally, all different index weights of the green building energy-saving effect evaluation index layer can be calculated, as shown in Table 8.

Therefore, the corresponding scoring matrix can be constructed by using formula (4) and combined with the index weights at all levels of the energy-saving design effect evaluation system in Table 8.

Table 6: Energy-saving evaluation index system secondary index judgment matrix.

B_1	B_{11}	B_{12}	B_{13}
B_{11}	1	0.8	0.6
B_{12}	2.5	1	0.5
B_{13}	3	2	1

Table 7: Secondary index weight value of energy-saving evaluation index system.

Secondary index	Weight value
Feasibility of design scheme	0.124
Quality of external protection structure	0.216
Energy consumption	0.473

Table 8: Weight of indexes at all levels of energy-saving design effect evaluation system.

Primary index	Weight value	Secondary index	Weight value
Energy-saving design	0.136	Feasibility of design scheme	0.124
		Quality of external protection structure	0.216
		Energy consumption	0.473
Energy consumption	0.247	Lighting condition	0.103
		Energy utilization	0.185
		External environmental conditions	0.327
Daylighting condition	0.315	Indoor lighting condition	0.162
		Light transmittance of external window	0.538
Ventilation condition	0.063	Indoor ventilation	0.178
		Indoor air quality	0.349
		Outdoor ventilation	0.426

According to the grade classification of energy-saving effect evaluation of green buildings, it can be divided into five categories: excellent, good, medium, qualified, and poor, which is represented by integers 10, 9, 8, 7, and 6. According to the energy-saving evaluation method proposed in this paper, the comprehensive evaluation result M of energy-saving effect of green buildings is calculated as follows:

$$M = \begin{pmatrix} 0.21 & 0.17 & 0.35 & 0.23 & 0.13 \end{pmatrix} \cdot \begin{pmatrix} 10 \\ 9 \\ 8 \\ 7 \\ 6 \end{pmatrix}. \tag{5}$$

The comprehensive evaluation value of the energy-saving effect of the building project is 8.82, which is between good and medium, indicating that the energy-saving effect of the green building model reaches the expected goal.

7. Conclusion

As an important development direction of the modern construction industry, green building was inseparable from the wide application of BIM technology. This paper made full use of BIM technology, which had the function of integrating building information model and its simulation. From the perspective of reducing building energy consumption and maintaining the sustainable development of the ecological environment, this paper studied the energy-saving design method of green buildings based on BIM technology. This paper systematically expounded the design principles and design concepts of green buildings and gave the overall scheme of energy-saving design of green buildings. This paper deeply studied the energy-saving design elements of green buildings, which should be considered from the aspects of modeling software selection, envelope energy-saving design, and lighting energy-saving design and put forward the energy-saving analysis method of green buildings based on BIM. In addition, this paper also put forward the energy-saving effect evaluation method of green buildings based on BIM from the aspects of the design of energy-saving effect evaluation index system and the energy-saving effect evaluation model of green buildings. An example further verified that the energy-saving design method proposed in this paper had certain guiding significance for the field of green buildings [18]. The energy-saving design of green buildings based on BIM technology proposed in this paper can not only provide a reference for the in-depth research of BIM technology but also provide technical support for the wide application in the field of green buildings.

Data Availability

The labeled dataset used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Construction of Chinese Language Teaching System Model Based on Deep Learning under the Background of Artificial Intelligence

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The openness of modern network intelligent education provides a broader learning space for Chinese language learners. People pay more and more attention to network learning, and network intelligent teaching platforms are constantly emerging under this background. Intelligence is one of the most important characteristics of ITS. However, the current network teaching system is far from enough in the intellectualization of teaching content, form, and process. In order to improve the intelligence level of ITS, this paper studies the use of DL network with strong self-learning ability to build ITS. From the point of view of teaching students in accordance with their aptitude and accurately reflecting students' learning state and characteristics, this paper analyzes the influencing factors in students' learning process, puts forward factors such as students' learning style and learning habits into the construction of a student model, and designs the student model. The future trend of ITS is predicted, and it is pointed out that this field with attractive development prospect is worthy of further research and design.

1. Introduction

In the network environment, Chinese language teaching workers need to reexamine the traditional communication media and teaching mode from the perspective of teaching practice, change ideas and roles, order the disordered oral Chinese teaching resources, and organically integrate modern information means with traditional language teaching means [1]. Teachers should be good at using network resources to design the learning process, and use the network to obtain each student's learning information to regulate the learning process. Artistic Intelligence (AI), computer science, pedagogy, psychology, and behavioral science are all involved in the development of intelligent computer-assisted instruction systems [2]. The ultimate goal of the study is for the computer system to take on the relevant responsibilities of education and teaching, i.e., to endow the computer system with intelligence so that it can partially replace teachers in order to achieve the best teaching [3]. The openness of modern network education unquestionably expands the learning space available for Chinese language instruction. People are becoming more interested in network learning, and network teaching platforms are continuing to emerge as a result. However, managers and teachers find it difficult to obtain dynamic learning information from network learners due to the increasingly complex particularity and temporal and spatial separation of the network education environment [4]. This results in a simple reproduction of the book content of resources and one-sided pursuit of quantity and scale in the push mode of teaching resources [5]. With a diverse group of online learners and a large number of them, determining how to collect reliable learning status information and provide personalized learning services has become a pressing issue [3].

With the development of multimedia technology and network technology, building a new Chinese language model that breaks the tradition and is not limited by region and time is an important issue that needs to be solved urgently [6]. In order to improve teaching efficiency and better train talents, people have been constantly exploring and trying to use new technologies and methods to improve teaching and learning methods and means [7]. At the same time, we hope to teach students according to their aptitude and carry out differentiated education according to students' different learning foundation, learning ability, and other characteristics [8]. However, due to a lack of teacher resources and teaching efficiency requirements, it has been impossible to teach each student according to their aptitude. The Intelligent Teaching System (ITS) proposal makes it possible to accomplish this goal. By creating an open teaching environment, modern education based on the Internet overcomes the time and space constraints of traditional education [9]. It is critical for effectively utilizing the resource advantages of various existing education systems, realizing rational resource allocation, and developing education. It also offers a viable solution to the problem [10]. This paper proposes and establishes an intelligent Chinese language network teaching system model to address the shortcomings of the existing network teaching system.

Intelligent teaching is an important development direction of computer-aided teaching. It is an open interactive teaching formed by using computer to simulate the teaching thinking process of teaching experts and taking students as the center and computer as the medium [11]. Based on modern educational theory, intelligent teaching introduces the latest achievements of AI, psychology, cognitive science, and other disciplines into computer-aided teaching, seeks the mode of learning cognition by studying the characteristics and process of human learning thinking, and enables students to obtain knowledge through personalized adaptive learning, so as to achieve the purpose of real individualized teaching [12]. The research on intelligent computer-assisted instruction system in China started relatively late. The research work started is mainly concentrated in a few universities and research institutions intermittently, most of them are systems for research and demonstration, and few systems have been strictly evaluated [13]. With the rapid development of intelligent computer-assisted instruction system, it will play a positive role in promoting China's education reform. This paper constructs a Chinese language teaching system model based on deep learning (DL). Based on the analysis of the serious defects of adaptability and personalization in the current online learning system, and on the basis of development practice, this paper discusses how to extract parameters such as behavior data and performance information of online learners by using key technologies such as fuzzy evaluation algorithm and Neural Network (NN) in ITS.

2. Related Work

According to literature [14], language teaching workers in a networked environment must reexamine traditional communication media and teaching modes from the perspective of teaching practice, change ideas and roles, and realize the ordering of disordered Chinese teaching resources. Reference [15] obtains a framework and design pattern that can quickly construct a college English teaching system with clear structure and reliable performance through research on the modeling of college English teaching system using UML modeling language. The current network teaching platform, according to literature [16], has a wide range of learning contents, and each platform only focuses on cultivating students' abilities in some aspects, rather than cultivating all-round abilities of listening, speaking, reading, and writing. Literature [17] seamlessly blends modern information technology with traditional language teaching methods. According to the literature [18], teachers should be skilled at using network resources to design the learning process and obtaining each student's learning information to regulate the learning process. According to the literature [19], the student model is at the heart of ITS individualized teaching and is responsible for the systematic representation of students' knowledge level, cognitive ability, learning motivation, learning style, learning history change, and other data. According to literature [20], these issues in the current Chinese language network teaching platform must be addressed immediately, and it is critical to develop a comprehensive, interactive, personalized, and feedback Chinese language teaching platform. According to literature [21], the main function of a network teaching platform is to display students' characteristics and attitudes and to provide a foundation for the realization of intelligent teaching objectives, teaching contents, and teaching strategies. Literature [22] proposed that educational objectives should include cognitive ability, motor skills, and emotion, in which the objectives of cognitive ability are divided into six levels according to the complexity of intellectual activities. Literature [23] studies the modeling of network college English teaching system based on UML. Through in-depth research, the framework and modeling diagram of online college English teaching system are designed. Literature [5] proposes that the student model is formed according to the interaction and response history between the students and the system, which can be dynamically modified according to students' learning situation, and the system can carry out individualized teaching through the student model. In view of the shortcomings of the existing teaching system, literature [24] proposed an intelligent network teaching system model. Based on previous studies and the current situation of Chinese language network teaching system, this paper constructs a Chinese language teaching system model based on DL. It also classifies students' learning characteristics and provides different teaching strategies and teaching contents according to different characteristics. The model can dynamically establish a personalized learning environment according to the characteristics of students and can truly realize individualized teaching.

3. Methodology

3.1. Theoretical Basis of ITS Construction. The concept of DL is derived from the research of Artificial Neural Network. A multilayer perceptron with multiple hidden layers is a DL structure. DL combines low-level features to form a more abstract high-level representation attribute category or feature to discover distributed feature representations of data. The motivation for studying DL is to establish a NN that simulates the human brain's analysis and learning. It mimics the mechanism of the human brain to interpret data, such as images, sounds, and texts. DL is a general term for a type of pattern analysis method. In terms of specific research content, it mainly involves three types of methods: Convolutional Neural Network, self-encoding NN based on multilayer neurons, and deep confidence network [25]. NN has strong learning ability; that is, the main characteristics of training samples can be abstracted through training, so it has strong fault tolerance and memory association ability, can process information in parallel, and therefore has a faster information processing speed. Applying NN to ITS can effectively improve the system's intelligence, adaptability, and response speed.

The combination of computer-aided education and AI, as well as the use of AI in teaching, is referred to as ITS. The intersection of AI, cognitive science, educational theory, and other disciplines produces it. It can be used as an adaptive learning support system to provide individualized instruction, knowledge, and guidance to students with various needs and characteristics. ITS looks for the mode of learning cognition by studying the thinking characteristics and process of human learning. Simultaneously, it aims for personalized teaching; determining students' personal teaching methods and contents based on psychological characteristics, cognitive level, existing knowledge base, cognitive structure, learning habits, learning style, and motivation; and selecting appropriate teaching strategies, in order to provide students with learning contents and progress that are consistent with their learning characteristics. Students develop their abilities as well as their knowledge through personalized and adaptive learning [26]. ITS is a new method and a new way to realize the modernization of teaching means, as it can fully exploit students' enthusiasm, can assist students in developing their intelligence and ability, and is a new method and a new way to help students develop their intelligence and ability. Expert model, student model, teacher model, and intelligent man-machine interface are the four main components of a typical ITS. The basic structure of ITS is shown in Figure 1.

The student model is one of the core components of ITS intelligence, and ITS can use it to implement personalized teaching for learners. A student model is a data structure that depicts the cognitive characteristics of learners. On the one hand, it keeps track of the learner's name, gender, number, and other basic information; on the other hand, it accurately reflects the learner's knowledge level, learning ability, psychological state, and other factors. The model of students changes dynamically in response to interactions between the students and the system, as well as the learning situation, and serves as the foundation for the system's determination of teaching strategies and resources. The expert model is used to represent relevant knowledge in the teaching field, as well as problem-solving knowledge that experts can use to solve related problems [27]. As for the teacher model, its primary responsibility is to choose appropriate teaching materials and present them to students in appropriate formats, while adhering to certain teaching principles. The key to this module's operation is knowing how to organize the teaching content, or how to teach. The Intelligent interface serves as the system's and users' interactive interface, providing intelligent multimedia knowledge input, user information and behavior acquisition, and knowledge output for other modules. Natural language processing, knowledge base maintenance, student model initialization, teacher model adaptive adjustment, and other functions are all part of the ITS intelligent man-machine interface.

Student model is a data structure representing learners' cognitive state, and it is the basis of ITS intelligent teaching. The dynamic structure of the student model shows the formation and relationship of the four components of the ITS in the learning process, as well as their roles in teaching decision. It can be seen that the student model is a dynamic structure, which tracks students' learning activities. By analyzing students' learning behaviors, it records and adjusts the information describing students' personalized characteristics, such as their knowledge structure, learning ability, and learning habits, so as to draw new teaching strategies. Among them, the decision-making mechanism is in the central position, and its functions are maintenance of relevant databases, generation of decisions, resolution of decision conflicts, etc. The dynamic structure of the student model is shown in Figure 2.

At present, there is a lot of research on ITS, including some student models, but these student models generally have some problems such as lack of intelligence. Student model is the most difficult part of ITS design at present, and it is also a hot issue in ITS research. Therefore, constructing a suitable student model is the focus of ITS construction. The model should be able to timely and correctly reflect the essential characteristics and state of students' learning behavior; that is, it reflects students' mastery and understanding of a certain learning content, learning style, habits and learning ability contained in learning behavior, etc. At present, students' models are generally classified into covering model, differential model, deviation model, and cognitive model.

In the covering model, the domain knowledge that students want to learn and its constraint relation are represented as a directed knowledge structure diagram, the learning state of students is regarded as the subgraph of this diagram, and the learning process is regarded as the approximation process of the subgraph to the original diagram. The system based on this model can get the defects of students' knowledge structure according to the comparison between the domain knowledge structure diagram and the students' knowledge state diagram, so as to recommend the contents to be learned to students. The deviation model records the deviations of the students' problem-solving path from the expert path. These deviations describe some deficiencies of students in this knowledge point and can give specific remedial measures according to the types of deviations. The cognitive model reflects the differences in cognitive ability and cognitive structure of each individual learner. By analyzing the cognitive differences of students, we can understand their initial learning ability and

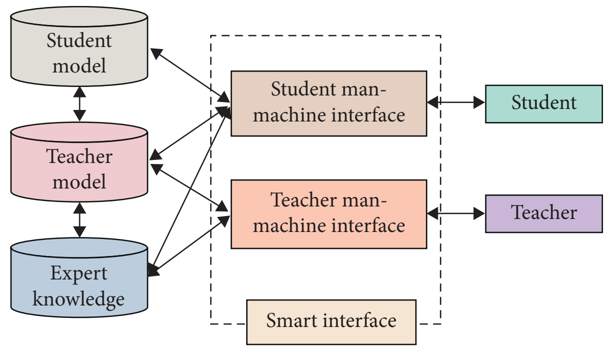

Figure 1: Basic structure of ITS.

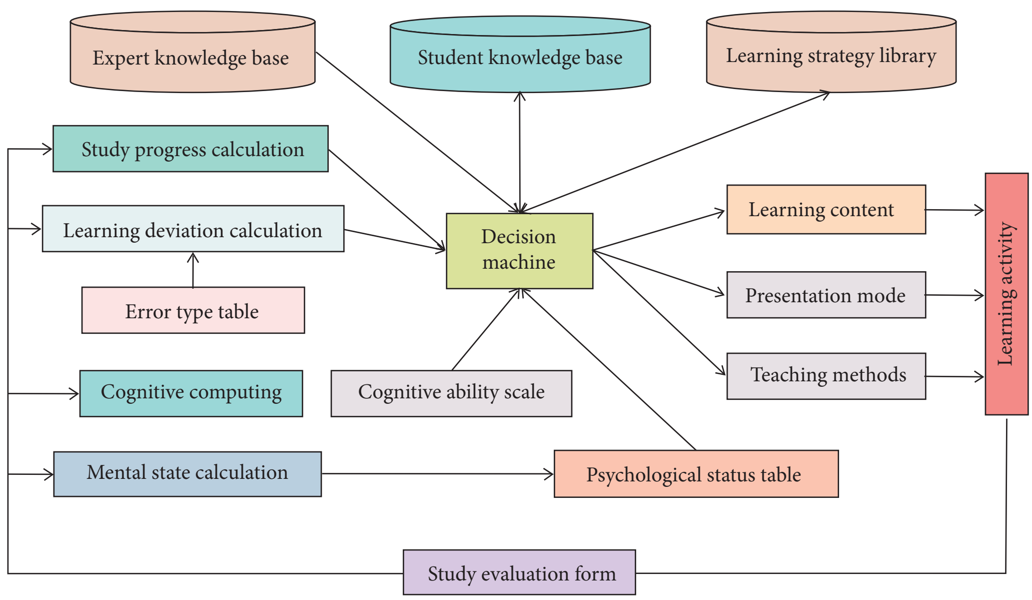

Figure 2: Dynamic structure of student model.

knowledge structure. The purpose of analyzing students' cognitive ability and cognitive structure is to formulate effective teaching strategies for specific teaching tasks. The differential model divides learners' knowledge into two parts: the pre-grant and the knowledge beyond the pre-grant, which is further expanded than the covering model, but its essence is the covering model.

3.2. Construction of Intelligent Teaching System. Based on the idea of intelligent teaching, the architecture of intelligent network teaching system is designed as three-tier B/S structure: user interaction layer, teaching application layer, and database server layer. The user interaction layer includes the interaction interfaces of students, teachers, and system administrators and realizes the interaction between the system and users through browsers. The student interaction interface is the individualized teaching content and learning interface provided by the system for different learners. Students log in to the system first and then participate in the pre-assessment test voluntarily, so that the system can get a preliminary understanding of students' knowledge level, cognitive ability, learning style, favorite learning strategies and so on. In the follow-up study, the system will select the learning contents in the teaching knowledge base that are suitable for students' characteristics and actual level according to the students' learning history, interaction with the system, and performance in the system diagnostic test and dynamically organize students' learning by the teaching strategies in the teaching model. During the learning process, the system dynamically generates the teaching process according to the student model.

Students can choose, judge, and deal with a large amount of knowledge using an intelligent reasoning mechanism in the intelligent teaching assistant system, which makes the learning content more targeted and improves the learning effect. The foundation of all development is system analysis, which is an important stage of software engineering. In the stage of system analysis, an accurate understanding of the system requirements and the internal operating mechanism of the system is helpful in accurately grasping the system requirements, so that the specific content of software development can be correctly determined. To fully understand the users' requirements for the system, we should complete the work of determining the content of system requirements, determining all involved elements, and establishing corresponding models for the current problems to be solved through system analysis.

After learning a knowledge point, students first consolidate their knowledge through corresponding exercises and then assess their cognitive ability through tests. The test questions of each knowledge point include three types: single-choice questions, judgment questions, and fill-in-the-blank questions. Each question can test at least one of the above six cognitive abilities. When students test, if they answer a question correctly, the cognitive ability of one or more items corresponding to the question will be 1; if they answer the question incorrectly, it will be −1; and if they do not answer it, it will be 0. After the students finish the questions of a certain question type, they can calculate each cognitive ability of the students in this question type as follows:

$$r_i = \frac{n_{ij}(1)}{n_{ij}(1) + n_{ij}(-1)}, \quad i = 1, 2, \ldots 6. \tag{1}$$

Among them, $1 \le j \le n$, where n is the number of test questions of this question type. $n_{ij}(1)$ is the number of times the i-th cognitive ability is answered correctly in this question-type test. $n_{ij}(-1)$ is the number of wrong answers to the i-th cognitive ability in this question-type test.

Suppose the test question types for each knowledge point include multiple choice questions, true or false questions, and fill-in-the-blank questions. According to (1), the cognitive abilities of each question type are calculated to form the cognitive ability evaluation of all question types. The matrix is as follows:

$$R = \begin{bmatrix} r_{11}, r_{12} \ldots r_{16} \\ r_{21}, r_{22} \ldots r_{26} \\ r_{31}, r_{32} \ldots r_{36} \end{bmatrix}. \tag{2}$$

Among them, $r_{11} \sim r_{16}$ represent the evaluation values of the six cognitive abilities of single-choice questions. $r_{21} \sim r_{26}$ represent the evaluation values of the six cognitive abilities of true and false questions. $r_{31} \sim r_{36}$ represent the evaluation values of the six cognitive abilities of the fill-in-the-blank question.

Knowledge base, as a crucial component of an intelligent teaching assistant system, primarily provides a guiding, adaptive, open, and operable framework, as well as service facilities. It also provides a standardized knowledge input organization for various disciplines' knowledge, as well as other teaching resources that are organized and managed in accordance with it. This will allow users to create their own knowledge system, providing a solid foundation for the development and integration of all types of knowledge applications. In addition, the core knowledge in the teaching field will be decomposed into interrelated knowledge points, forming a knowledge tree, with a visual and operational knowledge tree editing interface that makes it easy for teachers to input teaching knowledge into the knowledge base.

The whole processing process of NN is a quantitative process for students' participation in a course. The system divides the degree of participation into three levels: positive, general, and negative. The input of NN includes n variables such as the evaluation value of the three levels of participation, discussion, resources, learning progress, and the frequency of browsing the course web page. The degree of students' participation in the course is selected as the output node, which actually completes a nonlinear mapping from n-dimensional space to one-dimensional space.

$$\begin{aligned} F_{bp}&: X \longrightarrow Y, \\ X &= \{X_1, X_2, X_3, X_4, \ldots, X_n\}, \\ Y &= \{Y\}, \end{aligned} \tag{3}$$

where X_1, X_2, X_3 represent the evaluation values of 3 levels of participation. $X_4, \ldots, Xn$ express the discussion situation, resource situation, etc. Y represents the degree of student participation in the course.

Learning evaluation table records the learning results of each knowledge point in the unit after each test, which is the basis for adjusting students' knowledge table and error type table, calculating cognitive ability, and then forming teaching strategies. The module of the expert decision-making mechanism can be regarded as the inference engine in the intelligent teaching assistant system. Generally, it adopts the method of combining two levels of reasoning, that is, reasoning based on semantic network and reasoning based on production rules. Among them, reasoning based on semantic network is used to determine the teaching content, while reasoning based on production rules is used to determine the teaching strategy. Different from rule-based reasoning, case-based reasoning is regarded as reasoning based on previous experience. Therefore, in some intelligent teaching assistant systems, case-based reasoning is adopted.

The calculation of cognitive ability is to solve the problem of quantitative evaluation and measurement of cognitive ability. According to the different methods of evaluation and measurement of cognitive ability, there can be different methods to determine the cognitive ability of students. Define the weights of various question types: $W = (W_1, W_2, W_3)$. The weight of a single-choice question is as follows:

$$W_1 = \frac{\omega_1}{(\omega_1 + \omega_2 + \omega_3)}. \tag{4}$$

The weight of the true or false question is as follows:

$$W_2 = \frac{\omega_2}{(\omega_1 + \omega_2 + \omega_3)}. \tag{5}$$

The weight of the fill-in-the-blank question is as follows:

$$\begin{aligned} W_3 &= \frac{\omega_3}{(\omega_1 + \omega_2 + \omega_3)}, \\ W_1, W_2, W_3 &= 1. \end{aligned} \tag{6}$$

Among them, $\omega_1, \omega_2, \omega_3$ are, respectively, the evaluation value of the average answer of each question type of a number of students after the test (the W_1, W_2, W_3 value is given by an expert at the beginning and can be dynamically adjusted after a certain number of student tests).

Use (2) and weight W to calculate the final evaluation results of various cognitive abilities:

$$\begin{aligned} E &= R \bullet W \\ &= (E_1, E_2, E_3, E_4, E_5, E_6). \end{aligned} \tag{7}$$

Calculate the comprehensive cognitive ability of students after learning this knowledge point:

$$S = \sum_{i=1}^{6} E_i \times M_i. \tag{8}$$

Among them, $M_i\,(i = 1, 2, \ldots 6)$ is the weight of a certain cognitive ability (the weights of the six cognitive abilities are given by experts). This is a model of the cognitive abilities of students. The learning strategy library keeps track of the learning strategies for each knowledge point acquired through decision in the next round of learning. The next round of learning may consist of relearning a portion of the knowledge from the previous unit or learning a new unit. Determine the learning content, knowledge presentation, teaching methods, and test question generation, among other strategies. In fact, the intelligent interface module is a component that allows the system and users to interact. It not only allows students to input and register their information, but also allows them to communicate with the system. Natural language processing, internal processing of man-machine dialogue, systematic knowledge base maintenance, initialization of student model, adaptive teacher model adjustment, and other technologies are examples of related technologies. This module provides an excellent setting for using negotiation, debate, conversation, and other teaching methods.

The student knowledge base describes and records students' learning progress and level, as well as the types of mistakes made by students in each knowledge point. "Mastery degree" means the students' mastery degree of this knowledge point, and the system can set a threshold. If the knowledge points with test scores higher than the threshold are considered as mastered, the system will no longer arrange learning. Below the threshold, the system will arrange to continue learning. In the vicinity of the threshold, it will prompt students to choose whether to continue to strengthen their knowledge. The "error number" indicates the types of errors made by students in testing this knowledge point. The system can get the corresponding error description information and learning tips from the error type table and provide them to students for targeted learning.

4. Results Analysis and Discussion

The cognitive model is an essential component of the student model. People have been studying the human cognitive process for many years. Although some progress has been made, because the human cognitive process is such a complex problem, establishing an ideal student cognitive model at this stage is only an ideal. We must first solve the problem of how to represent cognitive ability in order to determine students' cognitive ability. Students have a variety of preferences. Two preferences are taken into account in this design: knowledge teaching and knowledge presentation. The teaching method of knowledge refers to how students prefer to be educated, and the presentation of knowledge refers to the media in which learning content is presented. We can use graphics to individually represent the data in the model. This is a line chart with coordinates: time, degree of participation, and variable value of cognitive ability, as shown in Figure 3. It has the advantage of being able to intuitively reflect the changing trend of students' related data for teachers to analyze and choose from.

Considering that the student model is mainly used to reflect the dynamic characteristics of students in the learning process, it can provide personalized teaching services for learners. Therefore, we use graphics to represent the data in the model hierarchically. Under the condition of different combinations of participation degree and cognitive ability, the system can automatically choose teaching strategies as a guiding graph. Its advantage is that various teaching resources can be placed in nine areas, analyzed, and selected. The system can provide a brand-new resource service mode of customized service, instant service, and active service for students in different regions, and teachers can also adopt different teaching strategies for students in different regions. The time domain waveform of data distribution obtained by DL algorithm is shown in Figure 4.

It is necessary to consider the cultivation and improvement of students' knowledge memory, classification, induction, and deduction abilities in the ITS student model, as well as reminding students to use deep learning. Thus, the corresponding teacher model can adjust the learning content and teaching methods, while giving suggestions on learning methods, rather than simply letting students learn a certain part of the content again; compare and analyze the questions answered by students; find out the reasons; especially analyze and diagnose the causes of errors; and feed them back to the corresponding teacher model. If the students scored well on the basic knowledge portion of the test but poorly on the comprehensive application test, the students may engage in shallow learning, and the teaching system should provide reminders and suggestions on learning methods, so that the effect of ITS teaching students in accordance with their aptitude can be better reflected. We have experimented on the practicability of the Chinese language intelligent education system, and the distribution of students' scores before and after use is shown in Figure 5.

The experimental results show that most students think that the system can effectively promote students' Chinese language learning, especially their learning cognitive ability. The teaching methods are divided into seven types: focusing on details, detailed description, general description, examples, brief description, prompt, and review. Students can choose a teaching method according to their own characteristics at the beginning of school hours, and the teaching module dynamically adjusts the teaching method during the

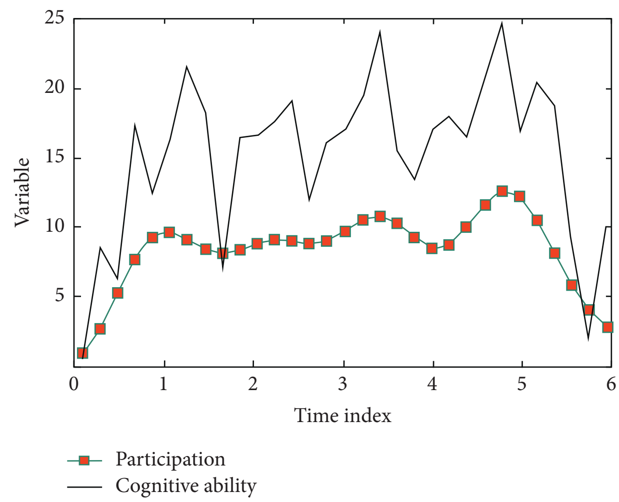

Figure 3: Student model line chart.

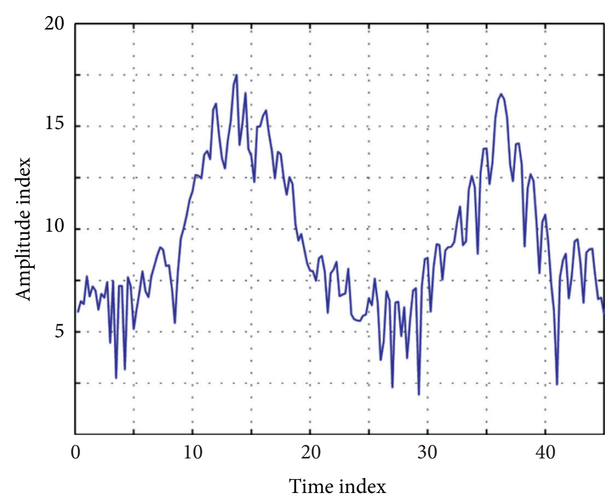

Figure 4: Time domain waveform diagram of data distribution.

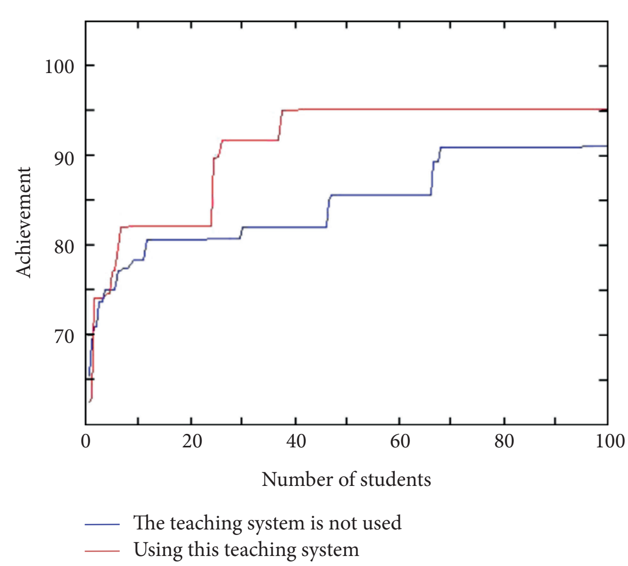

Figure 5: Comparison of student achievement distribution.

learning process. Teaching strategies are used to adjust the teaching content according to the student model in the teaching process. This strategy library has designed three teaching strategies. ① Continue to learn this knowledge point. ② Learn the prerequisite knowledge points for learning this knowledge point. ③ Learn the subsequent knowledge points of this knowledge point. In this experiment, 100 students were selected to use and score the original teaching system and this teaching system. The score data of the original teaching system and this teaching system are shown in Figure 6.

Students' study habits, their age, the correct knowledge they have and the degree to which they have mastered it, their study history, and their personality characteristics, among other things, should all be taken into account when designing the student model. Students' learning behavior in the student model includes total time, time spent learning a specific content, and time spent solving a specific problem. The accuracy rate drops to varying degrees, accompanied by a slight fluctuation, and the classification effect decreases as the feature dimension of Chinese language education increases. The relationship between the dimension of deep learning features obtained from two groups of experiments on the same batch of samples and the discrimination results is shown in Figure 7.

In the process of learning, students may be dissatisfied with or afraid of a certain course because they always make mistakes in doing the questions, thus taking a negative attitude to do or not do it. The system will repeat it according to students' performance until they learn, and students will become more and more bored, which makes the teaching effect not good. After adding students' emotions, the system can help students overcome this psychological state by appropriate means when students are in a bad state. Experiments are carried out on the data obtained in this paper, and the change trend of the target value with the number of iterations is shown in Figure 8.

NN modifies the connection weights of the network structure through adaptive algorithm, so that the network approaches the expected input-output relationship, can automatically adjust the parameters according to the changes of input data, and can optimize the system to better reflect the learning characteristics of students. The number of input level nodes is 5. The output layer is designed according to the students' learning state and characteristics to be expressed. At present, the set output includes the mastery of a certain learning content, learning methods, and learning habits. The number of hidden layers is set as needed. The model realizes the interaction between the users and the system, and it is the interface of two-way activities of teaching and learning, including student interaction interface, teacher interaction interface, and administrator interaction interface; at the same time, it includes the design of interfaces among the models. The model mainly uses web to express and communicate the content. Because of the untimely feedback of online learners' learning information, which is common in Chinese language teaching systems, it is difficult for teachers and managers to actively acquire the learning status of online learners. The intelligent network teaching system based on DL is designed and implemented in this section. The system uses NN and other technologies to analyze, mine, and establish student models in a shared environment of network "teaching and learning" with curriculum as the focal point. The basic teaching strategies used in the teaching process are determined based on the individual needs of students, and they are provided with a brand-new resource service mode of customized service, instant service, and active service.

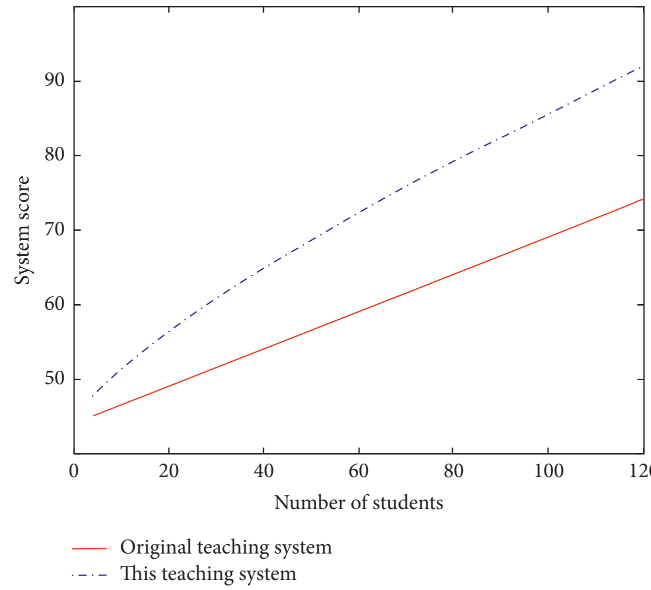

FIGURE 6: The use score of the original teaching system and this teaching system.

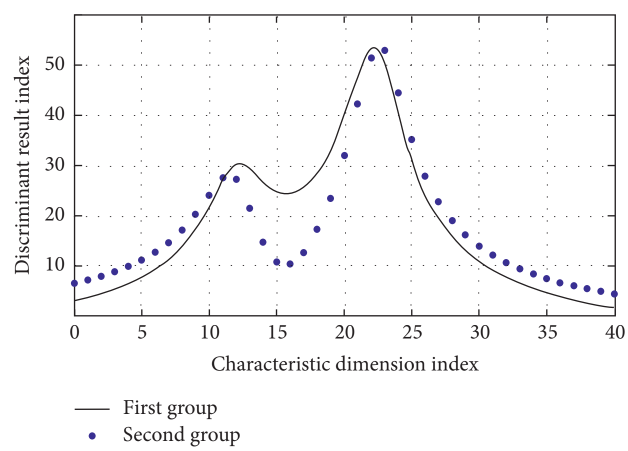

FIGURE 7: Characteristics change of Chinese language education based on DL.

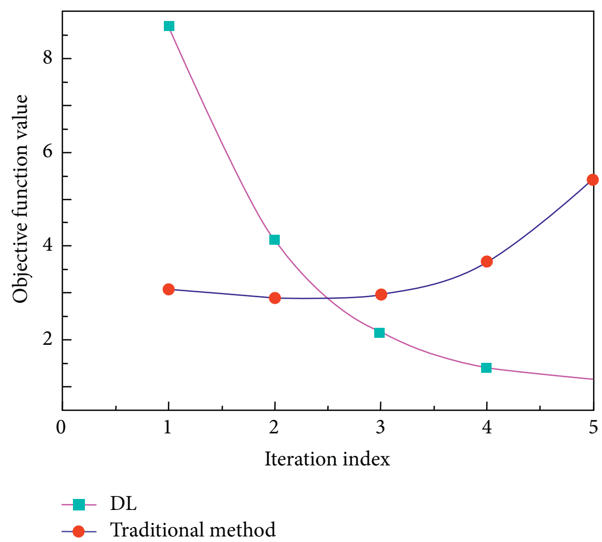

FIGURE 8: Trend of target value with iteration times.

5. Conclusions

In the information age, all things, environment, and information that can be used to achieve the goal of education and teaching can be regarded as educational resources. Therefore, in the process of Chinese language teaching, those that can be used to create Chinese language learning environment can be regarded as teaching resources. In today's educational reform environment, the intelligent teaching assistant system will play an increasingly important role. At present, there are not many achievements in this field in China, and even fewer systems can really be put into teaching practice. This field with attractive development prospects deserves our further study and discussion. Because the learning process and the factors affecting learning are very complicated, it is necessary to further study the factors affecting learning; the description, recording, and evaluation methods of learning activities; and the complex relationship between learning objectives, students' characteristics, teaching strategies, and learning effects and build a more scientific student model. In this paper, object-oriented modeling, teacher model, student model, and background support model are created in the system. It has solved the problems that the current development system is not fully functional and cannot realize personalized and interactive Chinese language teaching. The Chinese language teaching system model based on DL designed in this paper can adjust itself according to students' learning behavior; judge students' learning level, ability, learning style, and other student status and characteristics; and provide necessary information for teaching modules and expert modules, so that it can provide personalized learning resources and environment for students. At the same time, it is of great practical significance to improve the intelligence of ITS and teach students in accordance with their aptitude.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

The Interaction between Public Environmental Art Sculpture and Environment Based on the Analysis of Spatial Environment Characteristics

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The interaction with the public and the coordinated change with the environment are more important in public environmental art sculpture. To be more accessible to the public, public environmental art sculptures should be integrated with the environment and interact with the public. Paying close attention to the scale and volume design of sculpture is one of the elements that embody and express the connotation of works, as well as one of the objects that sculpture, as a member of environmental elements, must study and analyze thoroughly. Based on this, this paper investigates the relationship between sculpture and environment in public environmental art through an examination of space environment characteristics, with the goal of creating a public space environment in which public art sculpture, the environment, and people are all in sync. The improved AFSA (artificial fish swarms algorithm) model is used to optimize the landscape ecological pattern. The landscape index can be predicted and analyzed more accurately using a dynamic model of landscape pattern from remote sensing and a geographic information system. Experiments show that this algorithm's prediction accuracy has significantly improved, providing a solid foundation for landscape ecological management and planning.

1. Introduction

Sculpture is a very important link in urban development and an important part of environmental art. Because of the influence of the location and other factors, sculptures placed outdoors show certain permanent characteristics, so it is very important to properly handle the relationship between sculptures and the environment. As a part of the development of mainstream art, this creative form tries to break the historical gap between life and art [1]. Sculptors can use any medium including clay, stone, sound, light, and sound to create environmental sculptures. There is an inevitable connection between public art sculpture and the space environment. Sculpture must be structurally coordinated with the surrounding environment, and the coordination between the designed works and the space of public culture should also be considered [2, 3]. Only in this way can the public environment art sculpture and the environment promote each other, create a tacit atmosphere for each other, and then increase the charm of the whole space.

Sculpture can refine the cultural information in the environment's main body, allowing for the creation of a matching scheme of theme, content, and even formal structure, resulting in a harmonious and interdependent relationship between them [4]. Thus, art sculpture in the public environment belongs to the urban public form, is an art created and designed for a specific urban environment, is an artistic practice that occurs and unfolds in public places or public spaces, and maintains a mutually complementary and benign interactive relationship with other environmental elements, resulting in an integrated and organically unified overall urban environment [5, 6]. However, many public art sculptures have lost their aesthetic value due to a variety of factors. Instead of becoming beautiful scenery, they have polluted the environment and have become unfamiliar or even trash in urban areas. As a result, public environmental art sculpture in the cultural area should be capable of enhancing the environment and space atmosphere of the entire cultural area, and good sculpture works can evoke memories of not only the sculpture works themselves, but also the entire cultural area [7]. It is, however, also the most easily overlooked location. The integration with the surrounding environmental space, which is the display of integrated environmental space, is the goal of public environmental art sculpture. People need art sculptures in the public environment to enrich their lives, and sculpture is the best carrier for displaying the atmosphere of cultural areas.

Environment includes human environment and material environment [8], which is not only the bearing space of public environmental art sculpture, but also the living space of citizens [9]. The art sculpture in public environment with proper location, vivid image, and reasonable scale is an important landscape element of urban space environment, which can play the role of unified coordination and guidance of landscape [10]. In the end, contemporary public space art sculpture is an artistic expression form in the urban space environment, which is an important part of the urban space environment and has an impact on it. Whatever the theme, type, or form of the sculpture, it must adapt to the functions and characteristics of the surrounding space environment, as well as properly reflect those characteristics, in order to render and contrast the urban space environment, adjust the urban color, and enhance the visual feeling of public beauty [11]. Sculpture places a greater emphasis on public interaction and coordinated changes in the environment. It differs in content from previous environmental sculptures that emphasized theme and memorial, but it makes reasonable conception and design to create a space that interacts and coordinates with the public and the environment, based on the artist's imagination and various factors of environmental space.

2. Related Work

The research and creation of foreign public environmental art sculptures are very mature, the supporting facilities for sculptures in cities are perfect, and the developed countries in Europe and America are the most developed areas of public environmental art sculptures in the world. In major cities in Europe and America, there are almost all familiar sculptures as important urban cultural landscapes. Literature [12] holds that public environmental art sculpture is a kind of public sculpture art form that relies on outdoor public space in urban public space and can be appreciated by the general public. Whether it is western "environmental sculpture" or what Chinese scholars call "public environmental art sculpture," its foothold is the interaction between the social function of sculpture and the public, and its main content is to integrate the media of public environmental art sculpture into the daily life of the general public and serve the general public. Literature [13] holds that an excellent public sculpture often becomes the symbol of a city's public culture. However, due to the different places where sculptures are set and the different human environment, the public responsibilities of artistic sculptures are also different. Literature [14] holds that in terms of expression techniques and forms, outdoor sculpture should not only coordinate with the architectural appearance, but also play a role in enriching the active environment and space atmosphere. Literature [15] holds that urban space is a space composed of entities and a stage for people's daily life. It can exist between buildings, a street, a downtown area, even the whole city, or a larger urban space. Literature [16] holds that the restriction of space environment on public environment art sculpture is mainly manifested in two aspects, namely, the setting location and control elements of public environment art sculpture. Literature [17] holds that human factors are the comprehensive embodiment of emotional forms, environmental atmosphere, decorative effects, spatial feelings, and other aspects in environmental space, and finally, the human environment of urban environmental space is formed through these aspects.

The ecological pattern of a landscape is an important aspect of landscape ecology. Landscape ecological pattern analysis and evaluation can provide a solid foundation for landscape ecological management and planning, and it is the key to successful landscape ecological planning [18]. Various nonlinear data processing technologies are used to predict various landscape indexes based on the landscape pattern dynamic model of RS (remote sensing) and GIS (geographic information system) and landscape ecology as the theoretical basis. The surface is reconstructed from an undirected point set using a distance field isosurface extraction algorithm proposed in [19]. Because this nonlinear algorithm includes a complicated normal consistency check and isosurface extraction process, the model reconstruction process takes a long time. The surface is reconstructed using a noisy directed point set as input in the literature [20], but the reconstructed result still contains noise. Literature [21] uses a Voronoi diagram to decompose the scanned data before using Delaunay triangulation to reconstruct the mesh model. This method can accurately fit the scanned data point set, but ideal reconstruction results for noisy models and sharp features are difficult to achieve. To solve this problem, literature [22] proposed a user-assisted reconstruction algorithm. He requested that users place restrictions in areas that are unstable or imperfect, whether inside or outside. Literature [23] used distributed memory parallel processing to speed up the reconstruction of Poisson's surface, resulting in a good speedup ratio and little loss in reconstruction results. For a large number of point cloud data, literature [24] proposes a 3D surface reconstruction method based on principal component analysis. The three-dimensional surface of the pipeline is reconstructed using the principal component analysis method, and its accuracy is effectively improved, meeting the accuracy requirements of engineering survey. This reconstruction method, on the other hand, is appropriate for first-order surface continuity of the measured object.

3. Research Method

3.1. Research on the Interactive Relationship between Public Environmental Art Sculpture and Environment. Sculpture is a form of art that exists in a specific location. The combined visual and psychological effects of sculpture with the indoor and outdoor environment demonstrate the mutual penetration and integration of artistic and scientific functions. As a result, the sculpture must be appropriate for the environment, meaning that its volume, shape, and material must conform to the specific environment and space in order to produce the desired effects. Depending on the specific purpose of sculpture creation, the desired effect can be harmonious or antagonistic. Sculpture, in its role as art, provides a finishing touch to the outdoor environment, enhancing people's visual experience. The limitations in the process of sculpture creation are greater for indoor sculpture than for outdoor sculpture. Indoor sculptures are limited by regional functions, such as commercial, office, and residential areas, in addition to being suitable for lighting. Sculptures are differentiated by their regional functions.

The interaction of emotional communication of public environmental art sculpture is mainly carried out among three elements, namely, the subject, the object, and the interactive media, namely, the self-emotion of the designer of public environmental art sculpture, the attitude toward sculpture, the understanding of materials and the presentation of design ideas, etc. That is, the appreciators and acceptors of the public environmental art sculpture of the object, these audiences are bound to add their own feelings to the public environmental art sculpture and feel the creator's feelings; that is, the media public environment art sculpture itself, the public environment art sculpture is like a symbol, which conveys the designer's subject emotion to the audience object, and is the interactive medium and link between the subject and object.

The foundation of the 3D urban landscape model is the D-Digital City Information System. One of its key features is that it can manage terrain structure (digital elevation model), terrain texture (digital orthophoto scene), 3D artificial building structure information, and artificial building texture information. Furthermore, the system includes 3D urban model visualization technology, which employs virtual reality to represent transmission stereo models or virtual stereo models on a screen. The data model of 3D digital city is shown in Figure 1:

In different environments, sculpture gives people different visual feelings and different psychological experiences. Designers are required to pay attention to the interaction between sculpture and natural environment, coordination, and unity. Only when sculpture works become the carrier of nature, can they bring permanent artistic vitality to sculpture works, specifically when creating environmental sculptures, taking the characteristics of the natural environment as a starting point, and enriching the essence and connotation of sculptures by using relevant elements in the environment, so as to achieve the expected design effect.

The scale and form of environmental sculpture must be appropriate for the location of the sculpture, be consistent with the behavior and psychological activities of people in that location, and attempt to establish some sort of connection with the general public. The sculpture's form and theme are related to the public's behavior and psychology, resulting in a relaxed and interesting atmosphere. The ability to grasp the scale is a direct expression of the designer's own design thinking and design ability in the design of public environmental art sculpture. It may reflect the designer's intuitive understanding and grasp of the designed space. People can usually judge scale instinctively, so in a space with an inappropriate scale design, people will make incorrect judgments about the space itself and the size of objects in the space, lowering the environment's appeal. A good use of scale, on the other hand, can make a space feel beautiful.

In the design of public environment art sculpture, it is necessary to pay attention to the spatial relationship of various elements in the urban environment, grasp the hierarchy and identifiability of space, and make people feel comfortable physically and psychologically when they move in outdoor space, thus improving the utilization quality of space.

Excellent public environment art sculpture can stimulate people's aesthetic taste and artistic yearning, attract many citizens and tourists to watch and play, then condense the indispensable popularity of space places, and create a lively atmosphere. Therefore, clearly establish sculpture as a new concept of cultural image, and it can start from two aspects; first of all, improve the artist's cultural accomplishment, so that the artist can clearly realize that the sculpture and skills are full of cultural spirit. Secondly, realize that sculpture has various themes and different functions. Whether they are monuments of historical figures or portraits of important figures, they all have cultural meanings and are carriers of culture. Therefore, people should not underestimate the cultural significance of urban landscape sculpture. It often has an imperceptible cultural character, which exerts a subtle influence on people and becomes an indispensable connotation in social culture.

3.2. Layout Planning of Artistic Sculptures in Public Environment Based on the Analysis of Spatial Environment Characteristics. Different working processes for dynamic analysis of landscape ecological pattern depend on the objects, scales, and objectives, but the basic processes are as follows: objective determination, information collection, model establishment, preliminary scheme, scheme evaluation, planning formation, and management. The creation of models and the optimization of schemes are the most important aspects of ecological planning. Starting with the behavior of constructing a single fish and progressing through the local optimization of each individual in the fish school, AFSA (artificial fish swarms algorithm) imitates the foraging, clustering, and rear-end chasing behavior of fish. Obtain the global optimum.

The improved AFSA idea is adaptive to the environment during the searching process of artificial fish, such as foraging, clustering, and rear-end collision. Its purpose is to speed up the convergence speed and improve the accuracy of the algorithm. In this paper, the variable step size method is adopted, and the artificial fish adjusts the moving step size

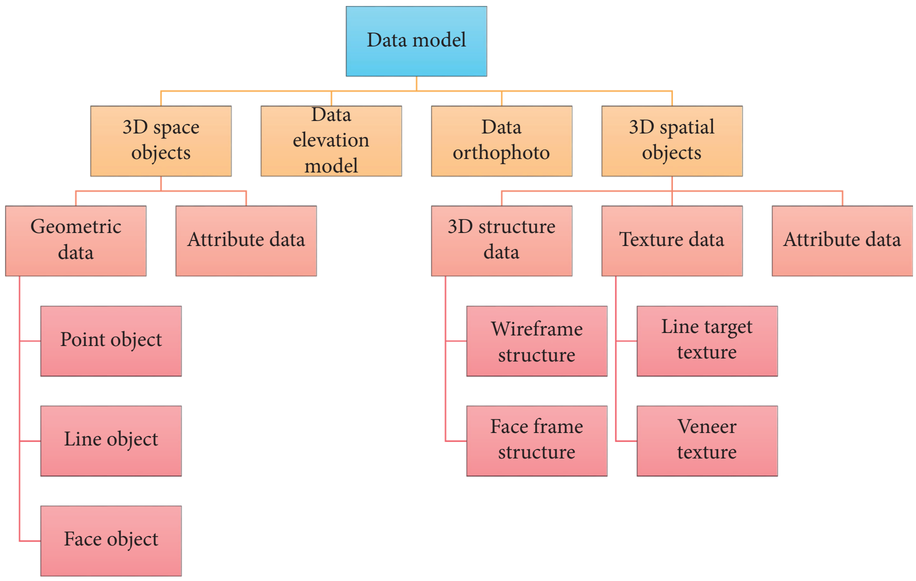

Figure 1: Data model of three-dimensional digital city.

according to the current environmental severity. The variable step size formula is as follows:

$$\text{step} = \frac{Y_m - Y_i}{Y_m - Y_w} \times \text{step}. \tag{1}$$

The current food concentration of artificial fish is Y_i, the maximum food concentration in the field of vision is Y_m, and Y_w is the lowest food concentration in the field of vision. This improved step size can get faster optimization speed in the initial stage of searching and reduce the probability of skipping the optimal value in the later stage, which can make more detailed optimization.

In order to automatically adapt to the phenomenon of fish aggregation, view gradually decreases with the increase of iteration times, and the adaptive formula of view is as follows:

$$\text{view} = V_{\max} \frac{(V_{\max} - V_{\min}) \times k}{it\ \max} \times \text{step}, \tag{2}$$

where $V_{\max}$ and $V_{\min}$ are the maximum and minimum value of view, k is the current iteration number, and it max is the maximum iteration number. At the initial stage of optimization, each artificial fish swims in a larger field of vision, expanding the search range of the algorithm and then gradually decreasing, so that the fish can search in a more detailed field of vision.

The shared function is used to correct the fitness value of individuals in the population to ensure the diversity of the population. The shared function is formed by the combination of coding difference and fitness difference. Assuming that there are two individuals x_i, x_j, the coding value distance between them is $d_1(x_i, x_j)$, and the fitness distance between them is $d_2(x_i, x_j)$, then the shared function $S(x_i, x_j)$ can be expressed as

$$S(x_i, x_j) = \begin{cases} 1 - \dfrac{d_1(x_i, x_j)}{a_1}, & d_1 < a_1, d_2 \geq a_2, \\ 1 - \dfrac{d_2(x_i, x_j)}{a_2}, & d_1 \geq a_1, d_2 < a_2, \\ 1 - \dfrac{d_1(x_i, x_j) d_2(x_i, x_j)}{a_1 a_2}, & d_1 \geq a_1, d_2 \geq a_2, \\ 0, & \text{other}, \end{cases} \tag{3}$$

where a_1 and a_2 are the niche radius. Incorporate the shared function into the fitness function of the individual to obtain the fitness function of the individual after correction:

$$\overline{f}(x_i) = \frac{f(x_i)}{\sum_{j=1}^{N} S(x_i, x_j)}, \tag{4}$$

where $\overline{f}(x_i)$ represents the revised individual fitness function, $f(x_i)$ represents the original individual fitness function, and N represents the total number of individuals.

When local search is carried out by subgroup, the worst fish X_w in subgroup learns from the best fish X_b in the group or subgroup. When learning, random replacement operators are used, and the two pixels are used as the upper left corner and the lower right corner to generate rectangular ranges, and the gene information of the learning target fish X_b in this range is intercepted and used to replace the genes corresponding to the worst fish X_w in the current subgroup to complete the update operation, as shown in Figure 2.

According to the fitness function, when the worst fish swarm X_w in the subgroup does not get better fitness after

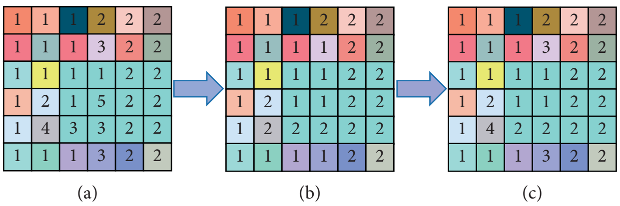

Figure 2: Update operation. (a) Worst fish. (b) Optimal fish school. (c) Worst fish after update.

updating operation, it is mutated, and the mutation operation flow is shown in Figure 3.

After the mutation, it is judged whether the area of landscape transfer exceeds the control of the probability matrix of landscape pattern transfer. If not, the mutation actually occurs; otherwise, the mutation does not actually occur.

When the point cloud dataset is added to the octree according to the set maximum depth, the octree is established. The node function of each node o of octree O is defined as

$$F_o(q) = F\left[\frac{q - oc}{ow}\right]\frac{1}{ow^3}. \quad (5)$$

The center of node o is oc, and the width of node o is ow.

Given a sampling point p, calculate the key sequence xyz of sampling point p and the sorted key sequence. The xyz key sequence of sampling point p is calculated from high to low. At $d\,(1 \leq d \leq D)$ depth:

$$x_d = \begin{cases} 0, & p, x < C_{\mathrm{dx}}, \\ 1, & \text{otherwise}. \end{cases} \quad (6)$$

D value sequence at depth xyz is defined as

$$x_1 y_1 z_1 x_2 y_2 z_2 L x_D y_D z_D. \quad (7)$$

It is easy to know that xyz sequence specifies the path from the following node to the current node, so when the depth is D, $3D$ bits are needed in total. At present, 32 bits can be used to represent k to allow that maximum depth of 10.

All sample points use xyz key sequence as sorting key. According to the coding principle, the xyz key sequence closer to the origin is smaller, and the xyz key sequence farther from the origin is larger.

4. Result Analysis and Discussion

The image was analyzed by RS and GIS technology, and the landscape elements were divided into seven landscape types, including cultivated land, garden, woodland, sandy wasteland, urban and construction land, water area, and unused land, based on the improved AFSA neural network research model of ecological landscape spatial pattern planning. Rasterize the image, with each raster measuring $300\,\mathrm{m} \times 300\,\mathrm{m}$. The remaining 20% of the sample is used as verification data, and the rest is used to train the improved AFSA model, yielding the corresponding landscape index prediction results. Several times, change the training times. The output results are stable, and the calculation results are shown in Figure 4.

The results show that the error values of the simulated output and expected output of the improved AFSA model samples are within ±4%, while the accuracy of the unmodified AFSA is generally ±6%. The training error of BP neural network can be controlled within ±7%. It shows that the output of the improved AFSA model is more accurate. The error is smaller. It provides a more accurate landscape pattern index. Provide scientific and powerful theoretical basis for the optimization of landscape pattern, and make the optimization of landscape pattern more reasonable.

Among all art forms, public art in the form of urban sculpture is the most likely to receive widespread public support. However, due to the nature of free public art appreciation and the characteristics of civilians, urban sculpture is no longer just a symbol of social status, but also reflects the public's deep meaning from the side. Nonetheless, urban sculpture is not a tool to solve social reality problems, nor is it a tool to blindly cater to and imitate the interests of the upstarts of the industrial and commercial circles. The degree of satisfaction is used to express people's recognition, and the method proposed in this paper is used to optimize the architectural landscape. Figure 5 depicts people's varying attention to square and pedestrian street evaluation factors, while Figure 6 depicts people's satisfaction with the optimized architectural landscape space. This paper assumes that the degree of satisfaction is divided into five different levels, and the corresponding score is 1~0.

The results of all evaluation factors are generally consistent after this algorithm has been optimized, as shown in Figure 6. People give more than "satisfactory" ratings to most architectural landscape evaluation factors, indicating that they are more satisfied with the Huaqiang North architectural landscape's optimized spatial layout. At the same time, it demonstrates that this algorithm is capable of achieving good architectural landscape spatial optimization. This demonstrates that the square satisfaction is the highest. The reason for this is that the square is the focal point for people's leisure activities, and its amenities and green space are well designed. However, on a pedestrian street, various shop decoration styles have their own merits, which are dazzling and easily cause aesthetic fatigue, and the vegetation greening rate along the street is low, resulting in low satisfaction.

Markov model is constructed by using Markov module of the software, and the transition probability matrix among various landscape types from 2020 to 2025 is generated, so as to predict the number transition of future landscape pattern in the county, which is used as the control condition in AFSA mutation operation to ensure that the optimized result of landscape pattern is consistent with the actual situation. The results are shown in Figure 7.

It can be seen from Figure 7 that forest land is the most active landscape type in the future evolution trend of county. The possible transfer area between building land and other landscapes is equally large, and the transfer amount is obviously larger than the transfer amount. The possible transfer area between sandy land and other landscape types is small,

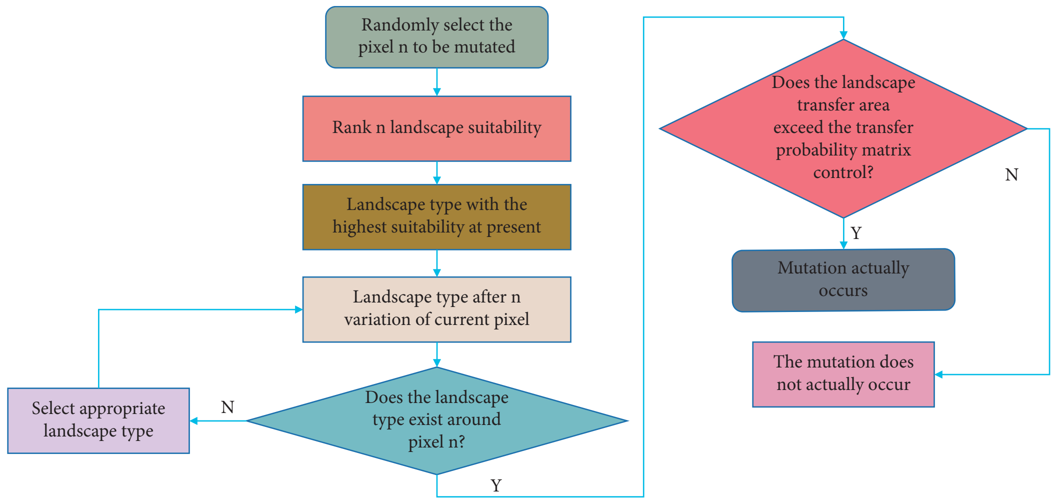

Figure 3: Operation variation.

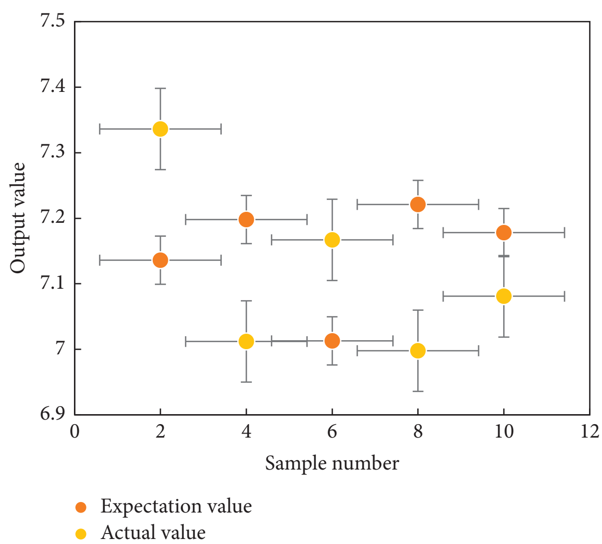

Figure 4: Comparison between simulation results and expected output.

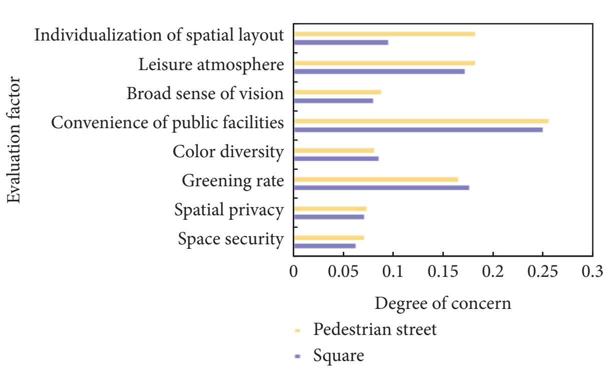

Figure 5: Different degrees of attention of evaluation factors of squares and pedestrian streets.

while that between sandy land and woodland is large. The landscape area of water body is small, the possible transfer area between water body and woodland and sandy land is large, and the transfer between water body and other landscapes is small. The possible transfer area of mountain landscape is the smallest among all landscape types.

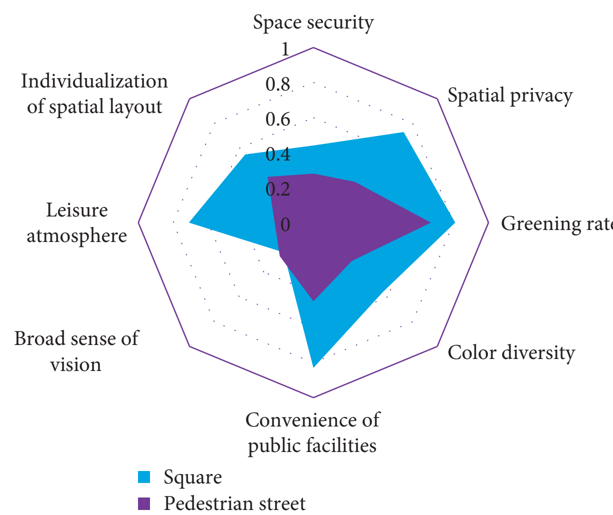

Figure 6: Satisfaction after optimization of architectural space.

Urban sculpture is a special material existence that exists at the level of form and acts on the level of image and meaning. They directly talk to our ideas and culture with external morphological features, which leads us to think about the spatial meaning, social life, and even human beings themselves. Therefore, the creation of urban sculpture should be based on people's visual psychological feelings.

Through the visual observation of the optimization results, it can be seen that the landscape aggregation degree of the two optimization models has been obviously improved, and the fragmentation of each landscape type has been well controlled. The distribution of landscape pattern in the study area in 2020 and the landscape aggregation index, the average landscape suitability index, and the transfer area beyond the control of the transfer probability matrix are calculated. The results are shown in Figure 8.

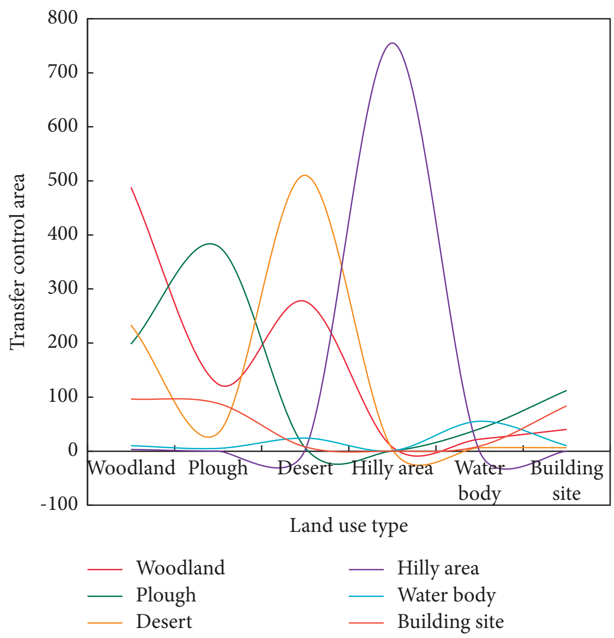

Figure 7: Landscape pattern transfer control area.

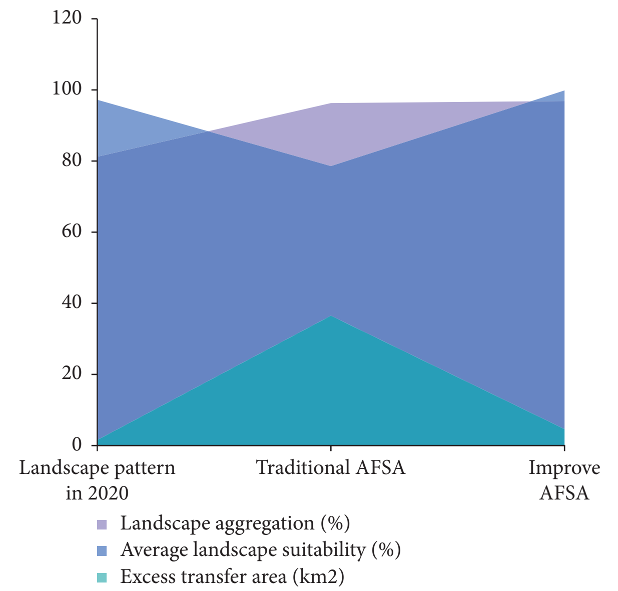

Figure 8: Comparison of indicators of landscape pattern optimization results.

Figure 8 shows how a higher landscape suitability index can ensure that county land is adapted to local conditions, prevent afforestation, reclamation of cultivated land, and other activities in areas with poor soil and water conditions, and play an important role in the rational use of county land. It differs from the transition probability matrix's control area in several ways. As a result of the excessive transfer area among some landscape types in the optimization results, there will be a disparity between the optimization results and the actual situation in the county, making the landscape pattern optimization scheme difficult to implement. As a result, the optimization algorithm must include control over the landscape pattern transfer probability matrix.

The experimental data used in this experimental system are the point cloud dataset provided by Poisson reconstruction algorithm official website, and the models used are bunny model and horse model. Analyze the horse dataset, and the specific situation of point average and area average generated by the horse dataset in the mixed parallel environment is shown in Figure 9:

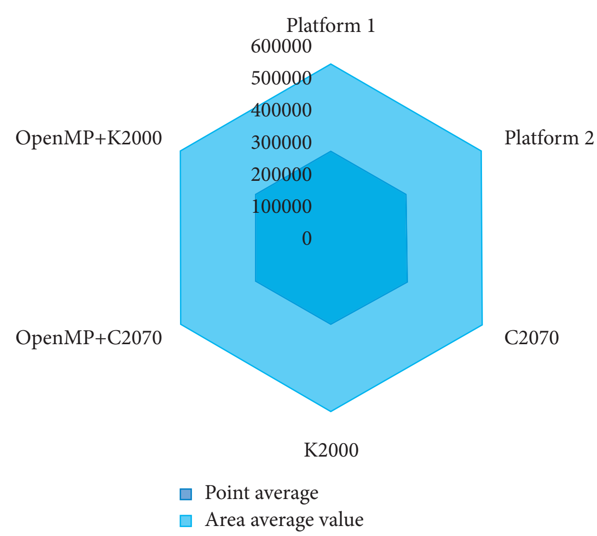

Figure 9: Experimental results of point average value.

However, modern cities no longer consider the division of urban space in a certain cultural or folk sense like ancient cities. Modern urban space is mainly divided by functional requirements, and then, it is designed and produced according to people's visual needs. For example, waiting rooms, mailboxes, guardrails, and other public facilities in modern urban streets are also important aspects to change the image of urban streets and shape the visual quality of cities, that is to say, in every street and public space of the city, starting from its functional requirements and human visual quality, from the aesthetic requirements of modeling and the unity of using functions.

The time-consuming results of various improved parallel algorithms are shown in Figure 10.

To sum up, compared with simply using any kind of acceleration equipment, a higher acceleration ratio can be obtained through hybrid and degraded acceleration technology. This is because the research makes full use of the characteristics of various tasks in the algorithm and assigns tasks to appropriate processing equipment for processing. In this way, high performance can be obtained by using these two types of equipment together. Therefore, when accelerating and optimizing the algorithm, consider using a hybrid parallel acceleration model to optimize and improve the algorithm, and allocate the computing tasks reasonably to obtain better optimization results.

In urban space, sculpture, like buildings, trees, and decorations, is an element of a city. Urban sculpture is an

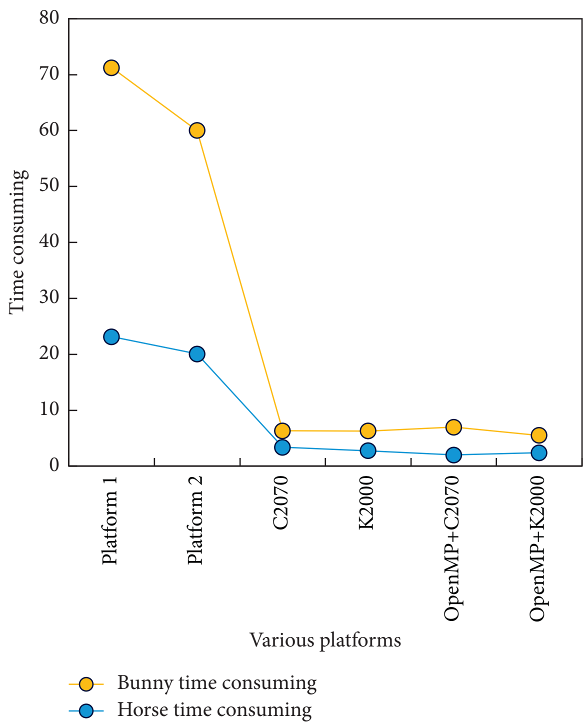

Figure 10: Time-consuming comparison of various platforms.

organic element that acts on the organizational structure of urban space. Unlike other elements, it has no specific function, so it will instead become the focus of a city in pure space. Only by paying attention to the necessity of this element can the city obtain a beautiful image and poetic praise.

Look for national characteristics and regional formal beauty in the overall beauty of the environment. Therefore, environmental sculpture should not only meet people's artistic quality requirements for their living environment, but also reflect people's constantly improving spiritual level in the cultural field. People's beauty of environmental art is no longer just the need for neatness and beauty, but the further pursuit of higher artistic realm and profound cultural connotation. Environmental sculpture is a kind of public art. It plays an important role in shaping the characteristics of the public environment and the humanistic environment of the city.

5. Conclusion

Public environmental art sculptures are not only an important part of people's daily lives, but they can also demonstrate the city's unique cultural charm. Because of their visual images, mature interactive public environment art sculptures can immerse the public in a deep cultural atmosphere in the urban environment. To improve the artistic value of sculpture, special attention should be paid during the design process to highlighting the city's uniqueness while also fully respecting local history and culture. The artistic sculpture of the public environment can be more closely combined with the city's root and thrive, fully demonstrating its unique city character, if sculpture planning is based on the analysis of spatial environment characteristics. Images are analyzed using RS and GIS technology. Improved AFSA can predict landscape indexes like category level and landscape level of landscape ecological pattern more accurately. It boosts the efficiency of landscape pattern optimization and provides a solid analytical foundation for achieving ecologically sound development.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Elements and Overall Optimization of University Self-Organizing Physical Education Teaching System Based on Holistic Theory

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The fact that self-organized physical education teaching systems in universities should have diversity and imbalance has been weakened, and we need to focus on the self-thinking, self-learning, and uncertain factors in the teaching process. The components of the entire teaching system are known as teaching elements. We cannot understand the integrity of teaching elements without understanding system theory. The teaching in physical education classes is the same way. This paper analyzes the elements and overall optimization of university self-organizing physical education teaching system using the methods of literature review and logical argumentation, starting from the perspective of holism and combining with the characteristics of physical education. The effectiveness and superiority of this model are tested by comparing sports performance data with ACOA (Ant Colony Optimization Algorithm) to optimize the sports video of SVM (Support Vector Machine). The findings show that the model can improve sports performance prediction accuracy, and the prediction results are more reliable, providing useful information for sports training.

1. Introduction

Many experts and scholars have conducted research on college physical education teaching models in recent years and have produced some impressive results, such as inductive analysis of typical college physical education teaching models, current state of college physical education teaching models, and experimental research on typical college physical education teaching models [1, 2]. Teaching in the classroom is a complex and comprehensive system with many components. The efficiency and quality of classroom teaching will be greatly improved if the individual vitality of these elements can be stimulated and their potential functions are fully realized [3]. Some philosophy of technology, which is emerging in the field of natural science, provides a new perspective for us to reexamine education, from the study of universal educational law to the search for situational educational significance.

There are five main elements within the university curriculum, disciplines, majors, curriculum contents, teachers, and students, which together constitute the university curriculum system [4]. However, the physical education in schools is responsible for the important physical exercise in the student period, but, through the investigation, research has found that there are many problems in college sports [5, 6]. In recent years, some scholars have applied the perspective of holism to the scientific research of physical education, which involves the exploration of the purpose of self-organized physical education, the prospect of the transformation of physical education paradigm, and so forth, and have made a useful discussion on applying the perspective of holism to teaching and training practice [7]. However, most of the results define self-organizing systems as individual students, and there are few results in analyzing the teaching process in which teachers and students participate together as a system from the perspective of holism. From the point of view of system theory, these factors that make up physical education teaching are a whole structural system, which not only belongs to the big system of school physical education but also contains its own subsystems such as goals, feedback, teaching contents, and teaching methods [8]. Teaching material (teaching content system) is the carrier of teaching theory and the object of teaching practice, which plays a key role in the overall framework of physical education teaching mode.

Teaching mode is defined as "a strategic system of relatively stable teaching procedures and methods that must be followed in the teaching process, which is formed based on teaching ideas and teaching rules, and includes the combination of various elements in the teaching process, teaching procedures, and corresponding strategies" [9, 10]. This paper builds on the nonlinear interaction between systems and the overall synergy effect to continuously develop in the direction of structure, organization, and multiple functions, from disorder to order and from order to higher order, in order to form positive influencing factors and evolutionary power and promote the optimization of physical education classroom teaching process.

2. Related Work

At first, the holistic perspective does not serve pedagogy subordinate to social sciences, and of course it also includes physical education, which is actually produced in natural sciences [11]. With the development of the times, more and more theories have explained and extended the holistic perspective, gradually improving the system into a group theory including many subtheories such as dissipative structure theory and synergetics, accelerating the evolution of holistic perspective in the field of natural science and laying a solid foundation for the field of auxiliary education in the future. Literature [12] holds that when interest factors occupy students' psychological tendency, students will show their physical strength and attention beyond usual and enjoy sports activities. Literature [13] holds that sports are an indispensable part in today's social activities and personal life. The sooner you realize this, the sooner you can shape a healthier body and mind. Literature [14] holds that the holistic perspective supported by many subtheories is in line with the current teaching needs. Literature [15] points out that today's traditional physical education relies too much on other organizations' interference, which limits the development of independent participation, self-thinking, and teaching methods in physical education. Literature [16] holds that it is necessary to improve the teaching methods of traditional teaching, which should be the center of our attention, highlight the subjectivity of students, and better impart knowledge. Literature [17] points out that although these traditional physical education teaching modes have played a certain role in the development of school physical education in China, they also show disadvantages in teaching; that is, they pay too much attention to sports technology learning and neglect the development of students' interests and the cultivation of independent thinking ability, which leads to some single physical education teaching methods. In literature [18, 19], by comparing the current teaching model with the needs of post-modern-curriculum reform, it is concluded that, nowadays, the traditional teaching mode has certain limitations, focusing on teaching, simplifying the teaching mode, and neglecting the cultivation of students' other qualities. However, modern physical education develops the teaching function of physical education from various angles, focusing on learning, implementing democratic teaching, and no longer sticking to a teaching mode but paying more attention to giving full play to students' learning initiative.

There are numerous sports video classifications available today. People used expert systems to classify sports videos at first. Expert systems, on the other hand, have high knowledge requirements and are unable to solve new sports video classification problems. At the moment, they are mostly computer-based automatic sports video classification methods [20]. According to literature [21], the current video similarity detection system has the problem of detection speed not being able to keep up with the actual production demand. The authors built a distributed platform for batch video similarity detection using cloud computing and the compound eye of insects, and the detection speed was greatly improved. Literature [22] created a distribution-based video content analysis platform. Offline and real-time video analyses are both possible with the platform. The platform is used in the testing stage to detect shot boundaries of multiple video segments at the same time, with a detection efficiency that is higher than that of a single machine. Literature [23] designed and implemented a distributed video processing platform that combines Storm and Hadoop, two distributed computing frameworks. In [24], a single frame image of video is parallel processed using Hadoop, and each frame block of the image is parallel processed using GPU. Literature [25] proposed a real-time video processing cloud platform based on embedded devices, on which Storm was deployed as a cloud computing environment and video streams were processed using the DL (Deep Learning) algorithm. Literature [26] proposed a video processing framework based on two cloud computing technologies, Storm streaming and Hadoop batch processing, and deep learning was employed to extract high-level semantic features from video data.

3. Research Method

3.1. Analysis of Various Elements of Physical Education. People usually equate the system with the whole. In fact, the system is a description of the whole. What people really care about is not the system but the whole. The purpose and essence of people focusing on the system lie in the whole. The essence of systematic holistic thinking is its wholeness, and system is actually an expression of wholeness; that is to say, from a systematic point of view, the wholeness of everything can be expressed by systematic terms and means. This is the system holism that we want to discuss.

From the static structure point of view, teaching is simply the activity where teachers teach students teaching content. Without any of these three, it cannot be called teaching. Without students, there is no teaching object; without teachers, teaching will lose its dominance; without teaching content, teachers and students will lose their teaching support. Trend shows that, to respect and develop students' personality, and attach importance to students' dominant position, insistence on diversification, flexibility, and individualization of teaching organization forms is a must. Therefore, letting students choose to participate in teaching classes with different project combinations in different periods can fully mobilize their learning enthusiasm, help to stimulate their interest and enthusiasm in learning physical education, and effectively promote the realization of the best teaching scheme.

In physical education teaching, good ideological quality is classified as the level of basic physical education quality. First, good ideological quality helps students to establish a correct world outlook, values, and outlook on life and plays a benchmark role for students to form a correct view of physical education quality. Second, with the rapid development of computer technology and information technology, various ideas and opinions are constantly emerging, students are in the whirlpool of information, and good ideological quality can improve students' cognitive ability. Of course, attention should also be paid to the teacher's self-development. In addition, the close cooperation between teachers can give students a better influence. Physical education teachers should investigate from many aspects such as skill level and sports theory. In teaching practice, they should not only teach students professional technical movements and sports theory knowledge but also cultivate students' good moral and will qualities.

A self-organizing physical education teaching system is an organic whole with specific functions which is made up of several interconnected and interacting elements. People are the main body of physical education and the main factor of the teaching system and the driving force behind the system's self-organization development. Individual differences as well as an overall identity exist among the various elements. Individual differences manifest as competition, whereas overall identity takes the form of synergy. They rely on one another, interact with and complement one another, and, through the teaching process, produce the overall effect (see Figure 1).

The model shown in Figure 1 shows that the integrity of the self-organizing system is the basic condition for this system to keep its own unique stipulation in motion. As a system, college physical education is a multilevel whole, which is not the simple addition of all the components but the organic combination of all the components. It reveals the distinctive characteristics where the interaction between teachers and students dominates the overall evolution of the teaching system. The main element of the physical education system is people, which has the characteristics of "initiative" and "liveliness." It is the key element of the system and plays a leading role in the operation and development of the system.

The course content of university is a process of getting rid of the rough and getting the fine in the selection of knowledge, and it does not form a direct correspondence with human activities. In addition, the course content is internalized into students' own knowledge structure through students' own choice and reconstruction in the process of transmission, and it is impossible to fully meet the university curriculum objectives. The integrated power thus formed is the leading force to promote the overall evolution and development of the teaching system. This is a new understanding of the integrity of the teaching system beyond the traditional holistic theory, and it is the essence of the integrity characteristics of the self-organized physical education teaching system.

The evolution and change of discipline is the most important factor in the evolution and change of the five elements of curriculum, and its fluctuation will inevitably lead to a change in specialty setting, followed by the selection and reorganization of learning materials, and a change in the numbers of teachers and students. The external environment of universities, particularly the development and changes of scientific knowledge, influences the development and changes of disciplines. Human cognition of the world produces scientific knowledge. It has a level and order of evolution, and it is evolving from a simple low level to a complex high level. As a result, it establishes the timeline for the evolution and change of the university curriculum system.

3.2. Overall Optimization of the University Self-Organizing Physical Education Teaching System. The system goes through ups and downs, producing random branches at the critical point, so as to achieve a new balance and order among the elements of the curriculum structure. This is the key to whether the university curriculum can realize its function. Relatively stable curriculum structure is an inevitable process of curriculum self-organization. The orderliness of university curriculum structure is manifested in "spatial orderliness" and "temporal orderliness." Therefore, the self-organization control of school physical education teaching must take into account the cultivation and combination of students' emotions, attitudes, and interests from the overall perspective of the system, so that students can apply what they have learned about physical education to practice.

With the advancement of multimedia technology, there are more and more types of image acquisition devices available, as well as an increase in the number of people participating in sports. Every day, mobile phones and cameras can collect a large number of sports videos, posing challenges for sports video management [1, 2]. The following is the principle of ACOA (Ant Colony Optimization Algorithm) optimized SVM (Support Vector Machine) sports video classification: To begin, sports videos are gathered, and a variety of sports video classification features are extracted. The features of sports video classification are then processed using the principal component analysis algorithm. A sports video classification model is established using SVM as the input and sports video category as the output, and the SVM is optimized by ACOA to produce the best sports video classifier.

SVM maps sports video classification samples by function $\phi(x)$ and then carries out the following processing in high-dimensional space:

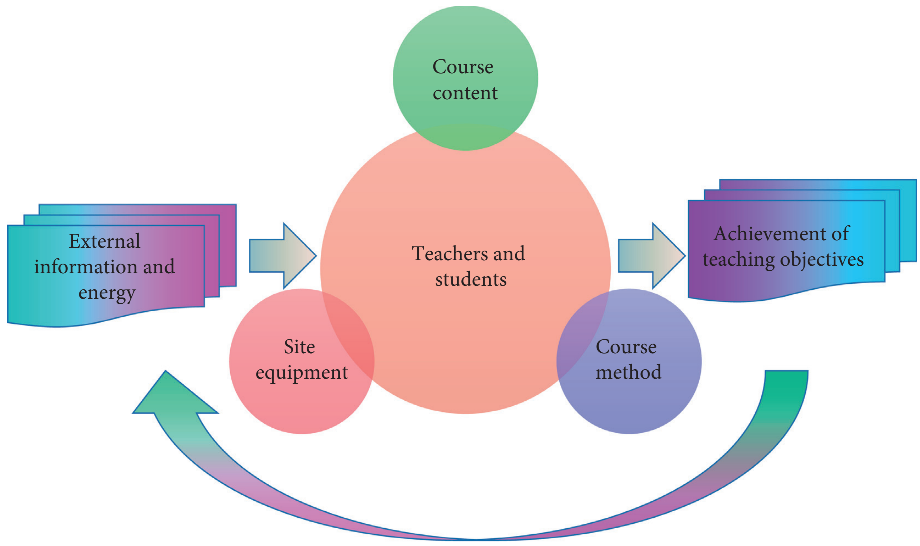

FIGURE 1: Sustainable operation of the university self-organizing physical education teaching system.

$$\min_{\omega,b,\xi} J(\omega,\xi_i)=\frac{1}{2}\omega^T\cdot\omega+C\sum_{i=1}^{l}\xi_i^2,$$
$$\text{s.t.}\quad\begin{cases} y_i=\omega^T\cdot\omega(x_i)+b+\xi_i, \\ \xi_i\geq 0, \\ i=1,2,\ldots,l, \end{cases}\tag{1}$$

where ξ_i^2 is the classification error and C is the penalty parameter.

According to the pheromone size left by ants, the next transfer probability of each ant is determined as follows:

$$p(i)=\frac{e^{T_0(\text{BestIndex})-T_0(i)}}{e^{T_0(\text{BestIndex})}},\tag{2}$$

where BestIndex represents the maximum pheromone concentration.

The pheromone depth is updated by the following formula:

$$T_0(i)=(1-\rho)*T_0(i)+\Delta(i).\tag{3}$$

Task scheduling is the process of allocating the best resources for the tasks that need to be completed, taking into account various factors such as time, cost, and resource utilization, in order to reduce task completion time and improve system resource utilization. HPSO (Hybrid Particle Swarm Optimization) is used to schedule the platform's tasks, with the goal of reducing task completion time as the algorithm's optimization goal. Figure 2 illustrates an HPSO-based task scheduling model.

For users, the main process of using the platform to process tasks is as follows:

(1) Initiate a task processing request to the user platform

(2) After receiving the user's task processing request, the task management module adds the task to the task queue

(3) The task scheduling module uses HPSO calculation to obtain the best task allocation scheme based on the status information of the computing cluster and the information of tasks to be processed

(4) The task distribution module distributes tasks to specific computing nodes for processing according to the scheduling scheme generated by the task scheduling module

(5) After the task processing is finished, the node feeds back the calculation result to the task management module, and the task management module informs the user that the task processing is finished

Assuming that there are N tasks and M virtual machines, the length of the particle position information is N, and the value of each element of the particle position is within the range of [1, M]. Formula (4) is an example of particle position coding.

$$X=\{x_1,x_2,\ldots,x_j,\ldots,x_N\},\quad 1\leq x_i\leq M,\tag{4}$$

where X represents the position information of a particle in the population, and for it contains any one-digit value x_j, j represents the task number, and x_i represents the virtual machine assigned to the task number i.

As all virtual machines process in parallel, the completion time of the task is the longest time needed to run among all virtual machines, and the calculation method is shown in the following formula:

$$\text{completeTime}=\max\{\text{totalTime}_i\},\quad i=1,2,\ldots,M.\tag{5}$$

Because the algorithm takes reducing the task completion time as the optimization goal, its corresponding fitness

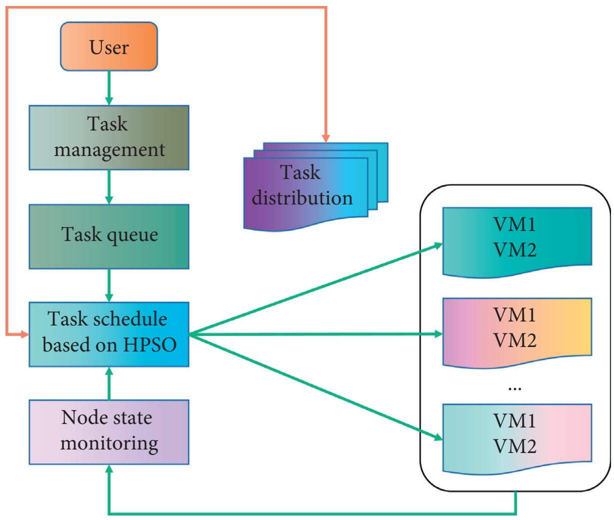

Figure 2: Task scheduling model based on HPSO.

function is shown in formula (6). The less the task completion time, the larger the fitness value.

$$\text{Fit} = \frac{1}{\text{completion time}}. \quad (6)$$

According to the number of iterations, the inertia weight is dynamically updated, and the velocity and position of each particle are simultaneously updated, and the best historical position of each particle and the global best position of the population are recorded.

Collect the sports performance data and process it with the following formula:

$$\hat{x}_i = \frac{(x_i - x_{\min})}{(x_{\max} - x_{\min})}, \quad (7)$$

where $\hat{x}_i$ is the sports result after processing; x_i is the original sports achievement; and $x_{\max}$ and $x_{\min}$ represent the maximum and minimum values, respectively.

After the prediction, the prediction results of sports performance are processed by the following formula:

$$x_i = \hat{x}_i \times (x_{\max} - x_{\min}) + x_{\min}. \quad (8)$$

According to the fitness function, the positions of fireflies are evaluated. Fireflies with weak attraction move to those with strong attraction, and the positions of all fireflies are updated.

4. Results Analysis and Discussion

The acquisition of high-level knowledge in the learning process is dependent not only on teachers' instruction but also on students' ability to learn on their own. Others organize the former, while learners organize themselves for the latter. Self-organization does not rely solely on students but rather requires the guidance and intervention of teachers. In the field of social sciences, self-organization demonstrates its scientificity, emphasizing the importance of guiding students to establish an orderly knowledge system, improving students' interest in learning, and promoting students' development as the fundamental idea of teaching design. The pretest and posttest experiments of EG (experimental group) are compared after the teaching experiment. The comparison results of the EG pretest and posttest experiments are shown in Figure 3.

According to the self-comparison results in Figure 3, it is shown that the open and cooperative teaching method from the perspective of holism can effectively improve students' learning interest, autonomous participation in class, and autonomous learning after class. After years of studying and living on campus, students have long been full of rejection of the teaching environment organized by him, so students regard physical education class as an opportunity to liberate themselves. When students find that sports still need a lot of repeated learning, students will naturally have resistance.

In order to maintain this achievement, it is necessary to enrich the teaching constantly, so that physical education can have more choices in content selection and purpose setting. From passive learning to active learning, we get the freedom and autonomy we deserve. On the basis of developing sports technology and maintaining physical and mental health, the openness of physical education is to develop students' subjectivity by using a more open teaching environment and a coordinated teaching atmosphere, so that the disorderly knowledge system can build an orderly knowledge structure in the open environment.

After the statistics, CG (control group) compares its own pretest and posttest experiments. Figure 4 shows the comparison results of CG pretest and posttest experiments.

After seeing the experiment, the scores of CG in four dimensions have slightly improved, indicating that, regardless of the teaching method used in physical education, students' interest in physical education learning can be significantly improved, but self-organized teaching can greatly improve the teaching effect in a short period of time. Five types of sports video data were chosen as the experimental objects in order to test the ACOA optimized SVM's sports video classification effect. Learn the training samples, establish corresponding sports video classifiers, and then classify the verification samples and count their sports video classification accuracy using the ACOA optimized SVM, the sports video classification method without parameter optimized SVM, and the sports video classification method of BPNN (BP neural network). The results are shown in Figure 5.

It can be seen from Figure 5 that this method can effectively reduce the error rate of sports video classification and obtain better sports video classification results.

The development of students' sports knowledge and skills and the construction of physical and mental health are all influenced by positive psychological tendencies. The formation and cultivation of autonomy are not only the purpose of teaching but also an indispensable feature for every member of society to move towards the continuous development of society. The inherent law of cultivation and students' self-organizing ability in the process of physical education study and exercise allow physical education to better cooperate with quality education and effectively develop students' physical and mental qualities.

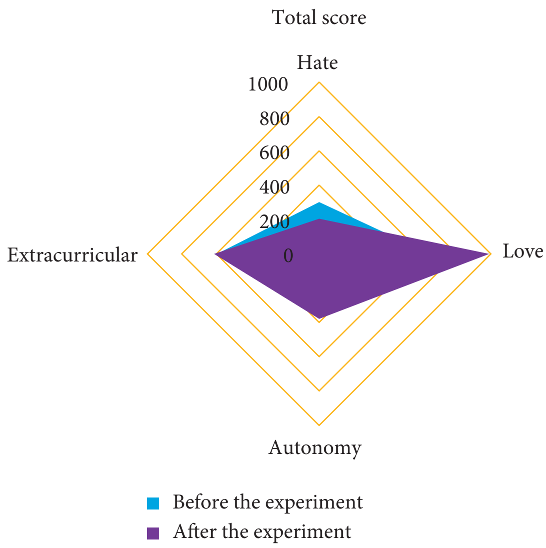

Figure 3: Comparison results of EG pretest and posttest experiments.

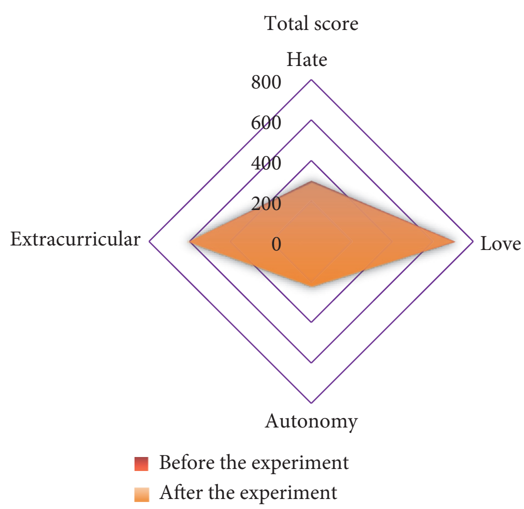

Figure 4: Self-comparison chart of CG pretest and posttest experiments.

Statistics of sports video classification time of the three methods are shown in Figure 6.

As can be seen from Figure 6, this method reduces the time of sports video classification and accelerates the speed of sports video classification.

Open physical education teaching demonstrates a wide range of learning objectives, all of which are complex and challenging. Students are part of a fast-paced information delivery system that is rich in differences and innovations. Knowledge is constantly being refreshed, new action structures are constantly being generated, and there is always something new to discover. In this way, knowledge gradually develops from disorder to order in a teaching situation with independent thinking as the primary component, and a reasonable external intervention force will aid in the formation of orderly knowledge. In the collective, there will be collaboration and competition. This migration force will be infinitely magnified and deeply portrayed in the minds of other students once an individual's technology model is recognized by the majority of people in the collective. Students who differ from the recognized technology model will consciously imitate and learn or even want to outperform their competitive behavior, develop autonomous and spontaneous learning, and then form an orderly and effective knowledge structure from a disorderly structure.

In order to verify the superiority of HPSO algorithm in convergence speed, it is compared with the algorithms in literature [22], literature [22], and literature [24]. A comparative experiment was conducted with 20 virtual computing resources and 500 tasks. The experimental results are shown in Figure 7.

When the number of iterations is 20, the task completion time of HPSO is obviously less than that of [22]. The specific reason is that the random method is used to initialize particle swarm in the algorithm of [22]. However, HPSO uses the method based on chaos opposition to initialize the population, which improves the diversity of the population, and makes the algorithm have a greater chance of searching for the relative optimal solution in the early stage than in the literature [22].

In the experiment, the number of tasks remained unchanged at 600, and the number of virtual machines was 10, 20, 30, 40, and 50, respectively. The task completion times required by literature [22], literature [24], and HPSO were compared. All the experiments were repeated five times, and the average completion time of five times was taken as the experimental result, as shown in Figure 8.

Literature [24] introduced the mutation operation of genetic algorithm into PSO, which ensured the diversity of population in the iterative process. HPSO also introduces the centroid of particle swarm to keep the diversity of the population. In addition, it uses chaos-based and opposition-based learning to initialize the population, which makes the initial diversity of the population higher, thus making the algorithm more likely to obtain the optimal solution.

Students are allowed to play freely for the sake of a broad teaching range. Teachers will guide and improve students' thinking as they take effective actions or responses to the teaching contents, in order to increase their participation, strengthen their self-learning, increase their interest in physical education, and guide them to improve their existing knowledge structure through mutual cooperation and reasonable competition in physical education. Physical development of students can be accelerated, and classroom quality can be improved. How students' states change over time is observed, breakthrough points are identified, students are encouraged to keep approaching these breakthrough points, and, finally, the conditions for technological progress are created. The teacher is allowed to lead the students through a sudden shift in their interests.

In order to improve the prediction accuracy of sports performance, a sports performance prediction model based on firefly optimized neural network is proposed to solve the problem of determining the connection weights and thresholds of BPNN. Grey model, BPNN, and RBF neural network were selected for comparative test, and 1000 m running result was selected as the experimental object. Their results are shown in Figure 9.

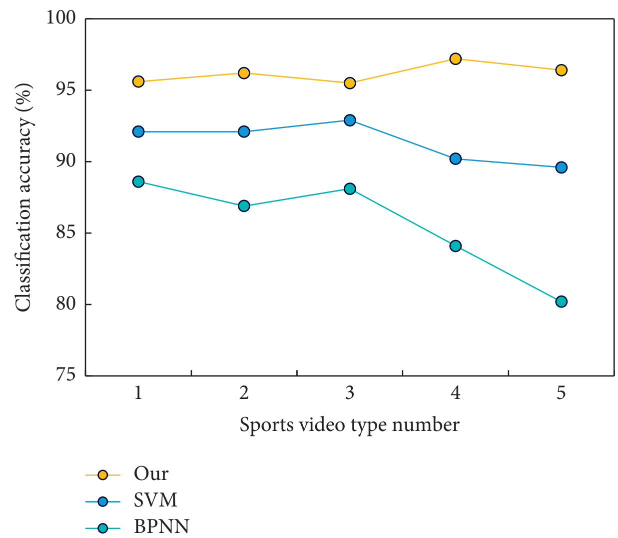

FIGURE 5: Comparison of accuracy rate of sports video classification.

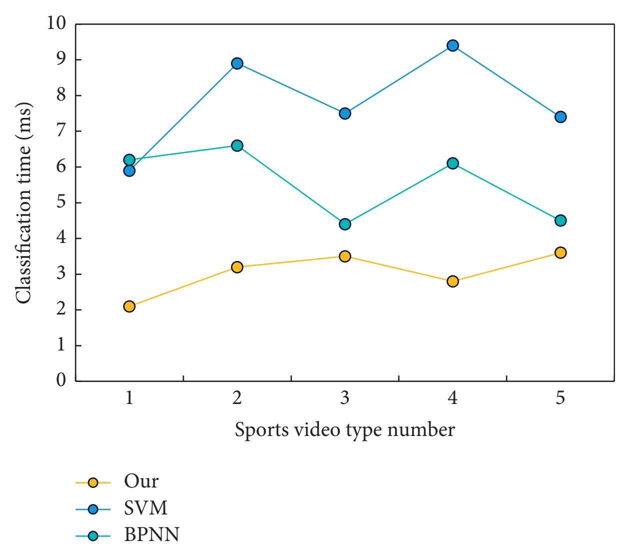

FIGURE 6: Comparison of sports video classification time.

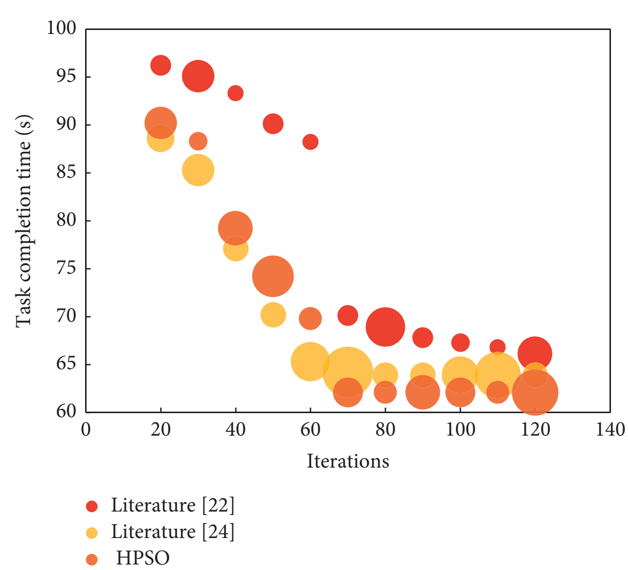

FIGURE 7: Comparison of convergence speed of different algorithms.

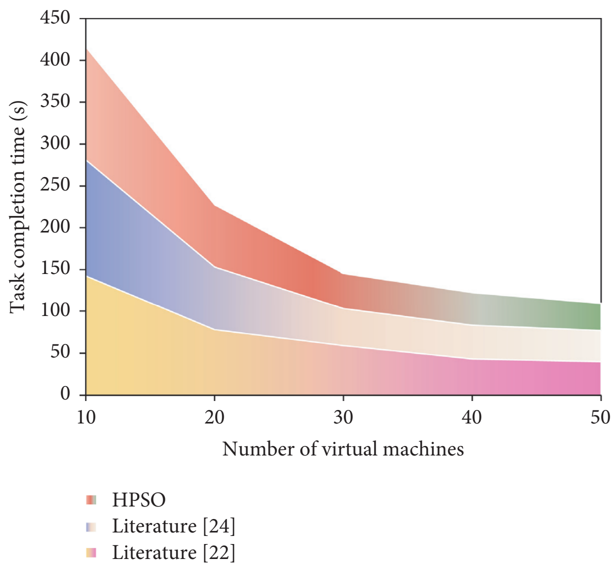

FIGURE 8: Comparison of task completion time under different virtual machines.

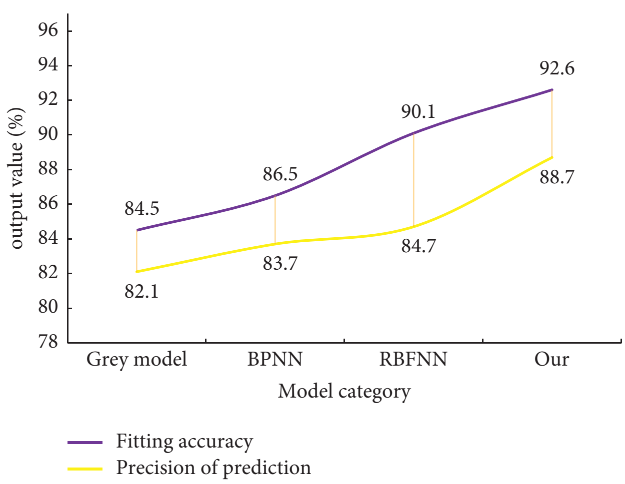

FIGURE 9: Universal test results.

As can be seen from Figure 9, the performance of athletes' performance fitting and prediction of this model is better than that of the comparison model.

In a physical education class, because students have to constantly adapt to the needs of teaching content, it is essential to adjust students' heart rate. Only under the appropriate heart rate condition can students' practice achieve the expected effect. In addition, because physical exercise is a gradual process in physical education, the sports load system not only reasonably grasps its rhythm in one class but also needs to consider the size of sports load according to the arrangement of sports activities (morning exercises, recess exercises, physical education class, extracurricular sports activities, amateur training, and competition activities) and teaching activities in a week to promote the healthy development of students.

Each school's situation is unique, and the physical education teaching mode is similarly unique. A comprehensive university, for example, with a large scale, multiple campuses, and a wide range of disciplines, may not be able to meet the needs of all students by using just one teaching model. Different disciplines and training goals, on the other hand, necessitate that teaching models reflect their own uniqueness on the basis of commonality. Several small groups of friends or classmates with varying levels, hobbies, and needs to practice are allowed, so that the interpersonal relationship between students and teachers is cordial and harmonious, boring and monotonous exercises become lively and interesting, and students' creative and enterprising motivation is stimulated, thus improving the teaching quality of physical education class.

5. Conclusion

For a long time, self-organization control theory has been widely used in the fields of nonlinear science and natural science, but there has been very little research into its application in college physical education. We should start with the teaching objectives, refine the objective structure, and create a multilevel objective system when teaching physical education classes. A new concept of physical education is formed based on the holistic theory, which attempts to establish a physical education teaching paradigm that focuses on students' subjective development and diversified transformation. The results of the HPSO algorithm show that it has some advantages over other algorithms in terms of task completion time and convergence speed. Sports video classification has a higher accuracy rate than other current sports video classification methods, and the error rate is controlled within the scope of sports video application, which overcomes the limitations of other sports performance prediction models, and the prediction results are more reliable, which can improve the scientific decision-making basis for sports training.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

All the authors declare no conflicts of interest.

Acknowledgments

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Research Article

Application and Development of Digital Enhancement of Traditional Sculpture Art

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Sculpture art, as an important carrier of spiritual civilization, also portrays a prosperous scene as an industry with urban and cultural development. Three-dimensional technology offers a new platform for sculpture creation, allowing for the digitization of sculpture works via electronic information technology, and the display of sculpture works in front of people via displays, facilitating the exchange and dissemination of information and promoting the growth and progress of the entire sculpture creation industry. We plan to use digital enhancement technology to conduct small-scale creation experiments on traditional sculpture works, discuss the method of GA (Genetic Algorithm) in image restoration processing, investigate the method of image segmentation processing based on the genetic algorithm, and propose the method of image segmentation processing based on the fuzzy membership surface genetic algorithm, in order to verify and solve the creation difficulties of traditional sculpture works.

1. Introduction

As time passes, new technological means emerge one after the other. The use of new technology has resulted in significant changes in the way artists create art. The use of digital technology in the design and production of sculptures is becoming increasingly common [1]. Sculptors are increasingly turning to computers to create virtual sculptures. Sculptors can not only design sculptures with computer software but they can also simulate the space environment in which the sculptures will be displayed for a better display effect [2, 3]. The creative process of sculpture art and even the sculpture itself have separated from the limitations of material materials thanks to three-dimensional modeling design, which expands the creative means of sculpture to the computer's three-dimensional virtual space.

Digital sculpture is a small branch of digital art. A digital sculpture is a combination of three-dimensional modeling technology and traditional easel carving art, and artistic creation by computer [4]. Digital sculpture, as a new discipline integrating art and science, has broad development space and application fields. Three-dimensional technology comes from life, develops in life, and feeds back into life. Three-dimensional digital technology refers to a computer-related science and technology, which identifies and processes images, sounds, characters, images, etc., through advanced cushion equipment, converts them into binary numbers "0" and "1" that can be identified and processed by computers, and carries out operations, processing, storage, transmission, and restoration through a series of algorithms [5, 6]. Sculpture, as a traditional art category, plays an important role in human history. As an important cultural carrier, sculpture art has always had extraordinary significance in human social and cultural life. It is for this reason that the combination of contemporary sculpture art and the most advanced digital technology can be regarded as the inevitable trend of the times and the inevitable result of the development law of sculpture art [7]. With the support of digital technology, the creation accuracy of sculpture works will be significantly improved, and the creation cycle and cost will also be reduced, saving artists a lot of time and energy to invest in more artistic creation.

It has been more than ten years since virtual technology was used in sculptures. It has progressed from a supporting technical tool to a singular artistic expression in the hands of artists [8]. After a long period of development and improvement, 3D technology [9] now has a powerful data simulation capability, allowing it to simulate and display various detailed aspects in a virtual environment, such as light and shadow, object material and color, motion track and way, and geographic location, through practical operations. In this paper, digital technology is combined with traditional sculpture art's creative methods, and the research of a sculpture art creation method based on digital technology is presented in order to meet the demand for increased accuracy and efficiency in sculpture art creation.

2. Related Work

Although digital technology has been introduced into the process of sculpture art creation by some artists, most of the known research studies and attempts at present are the two combinations between 3D scanning technology and 3D printing technology, or digital carving technology and 3D printing technology, but it is rare to study the comprehensive application of the three technologies [10]. 3D printing technology, as the key technology of digital technology to finally create entities, has a great influence on the realization of the idea of digitalization of sculpture art. Literature [11, 12] is eager to use digital technology in their own artistic creations, and they regularly hold personal digital work exhibitions to demonstrate the benefits of science and technology to art and to encourage young artists to pursue careers in this field. Literature [13] investigates the characteristics and connotations of art under the influence of numbers, with the help of calculations. The majority of studies in literature [14] are focused on digital media, virtual art, and digital aesthetics, with only a few theoretical studies on the use of digital technology in sculpture. On the one hand, only sculptures on yellow mud, Chinese painting on rice papers, and prints on copper plates, according to literature [15], can be considered true works of art. Computer graphics, on the other hand, are highly technical, untouchable, and emotionless, and thus cannot be called art. Literature [16] predicts that computers will evolve from rational technology to artistic beauty and that digital technology will have limitless applications.

Augmented reality technology is a technology that "seamlessly" superimposes information from the virtual world to the real world. By superimposing information generated by computers into the real world, users can achieve sensory experiences beyond reality. In Literature [17], using an unsharp mask to enhance images, the contribution of sharpening path is mainly controlled by adaptive filters; contrast enhancement is needed in detail areas; little or no sharpening is needed in smooth areas. Literature [18] proposed a subimage histogram equalization enhancement method based on exposure, and the exposure threshold was used to divide the original image into subimages with different gray levels. Literature [19] proposed a hybrid image enhancement algorithm, which is based on the contourlet transform of sharp frequency localization and adaptive histogram equalization. Literature [20] reset the coefficients of the Laplacian pyramid directly after decomposing the image with the Laplacian pyramid, which is easier to operate on the coefficients, but it will cause a halo. The initial weights of BPNN (BP neural network) are optimized using an improved GA in literature [21]. The simulation results show that this method effectively improves the convergence speed of the BP neural network by reducing the likelihood of it falling into a local minimum. Literature [22] proposed the concept of self adaptation, which adaptively adjusts the crossover rate and mutation rate in response to individual sensitivity and population diversity change, thereby improving GA convergence speed. A better GA (Genetic Algorithm) based on population dissimilarity was proposed in literature [23]. The algorithm uses a heuristic crossover strategy and can adjust the crossover scale, mutation scale, and mutation rate of each gene in the mutant according to the population's diversity, avoiding premature population convergence and speeding up evolution.

3. Research Method

3.1. Demand Analysis of Digital Enhancement Technology in Sculpture Creation. Digital art is an artistic means by which artists use computer technology as a support to simulate three-dimensional scenes through digital information. This way, artists' creative consciousness is brought into space from the plane, and an impossible thing is realized, which greatly improves the scope of art. The Internet's high-speed media has enhanced the distance between the audience and technology, and the aesthetic interaction between the audience and art [24].

In the information age, computer technology endows art with infinite possibilities, which makes its creation and expression tend to be diversified. In the art of sculpture, with the intervention of 3D digital software technology, a sculpture is presented to everyone with a brand-new look. The demand for digital technology in sculpture creation is manifested in two aspects:

(1) In the ordinary sculpture creation practice, using computer to engrave 3D model, the structure of the model is analyzed clearly at any time by marking, and undo and advance continuously, which is a function that traditional sculpture cannot achieve. Practicing the component model in the software is helpful for everyone to understand and master the structure.

(2) In some large-scale sculpture creation, it is necessary to enlarge the model according to the manuscript. In the real world, there are some errors in the data of the scanning model, which cannot meet the precise requirements of large-scale projects. However, the data of the model carved in the software are very accurate, which can ensure the accuracy of the scaled size.

Sculpture molding is a time-consuming and difficult process in traditional sculpture creation. First and foremost, the sculpture image must be designed. A draft or a sample can be used in the design process. Sculpture mud, clay, oil mud, pulp, gypsum, and other easy-to-form materials are commonly used to create samples. The clay sculpture is then made in equal or reduced proportion to the draft or sample. Of course, there are times when the draft or sample is not used, and the equal proportion creation is performed on the spot. It is necessary to construct the sculpture skeleton as well as screen, and suppress the clay for a sculpture before beginning to create the clay sculpture. Figure 1 is a schematic diagram of the sculpture-making process under traditional technical conditions.

In the aspect of 3D digital molding technology, it is necessary to have a deep understanding of 3D printing, engraving technology, and other digital molding technologies. To understand different molding processes, different molding materials, and basic properties of materials in 3D printing technology, understanding basic knowledge of these can predict the effect of shaping the work. Because for 3D printing technology, different molding processes are suitable for different molding structures; for example, a stereolithography apparatus process is suitable for a complex mechanism and precision requirements. Today's mainstream design software generally updates its version once a year, and each update will increase its function. In order to better create art, attention is always paid to software version upgrades, and new features of the software are constantly studied.

When using 3D digital modeling technology to create sculptures, it is essential to master the basic knowledge of sculptures and basic techniques of creation, and it is also necessary to master 3D digital software and fully understand related molding technologies. Cultural literacy refers to the sculptor's understanding, accumulation, mastery, and perception of human cultural knowledge.

To begin with, only when sculptors have a thorough understanding of human culture, particularly art culture, the sculptures they create can have full vitality because they bear the connotation of human culture, and they can perform the aesthetic education function that art is supposed to perform. Traditional sculpture art is rooted in a rich historical and cultural heritage, as well as a rich national culture. It is more easily accepted and recognized by the audience because it has a strong affinity with the audience's psychology and feelings. As a result, cultural genetic defects of new means can only be compensated for when digital sculpture creators use their own cultural literacy and integrate cultural factors into sculpture creation.

Secondly, sculptors must have the ability to discover beauty. Artists should be discerning and discover the beauty that ordinary people cannot find so as to remind people that there are always beautiful things in the world. Furthermore, an artistic expression ability is an essential artistic accomplishment for artists. Art expression refers to the process of using professional skills to express artistic thoughts, that is, artistic creation.

In addition, as a sculptor uses modern technology to create a sculpture, it is very important to have the quality of science, especially computer science. Combining cultural literacy, artistic literacy, and scientific literacy and creating excellent digital sculpture works is one of the necessary qualities for sculptors who use 3D digital molding technology to create.

3.2. Digital Enhancement Application of Traditional Sculpture Art. GA (Genetic Algorithm) is a kind of randomized adaptive search algorithm that draws lessons from natural selection and natural genetic mechanism in biology. Because GA is a global optimization search algorithm, it can quickly and effectively calculate complex nonlinear multidimensional data space. Using a membership surface instead of a threshold surface can also realize adaptive dynamic image segmentation based on pixel clustering.

Several key steps in the implementation of GA based on the fuzzy membership surface are as follows [25]:

(1) Chromosome coding. Because the membership surface is used to realize dynamic image segmentation, chromosomes are encoded into a two-dimensional matrix with membership function values of each pixel as elements. The membership function value is a real number within [0, 1]. For the convenience of operation, the membership function value of each pixel is quantized by 8 bits so that the solution space is $256^{M\times N}$.

(2) Initializing the population. Let the population size be K. Firstly, the gray range of the image is sampled at equal intervals, and K. thresholds are collected for global thresholding. Then, K membership functional value surfaces $u_2(x, y; T)$ about the background fuzzy set are calculated as follows:

$$u_2(x, y; T) = \begin{cases} \dfrac{1}{2}\left|\dfrac{f(x, y) - m_1(T)}{C}\right|^{\alpha}, & 0 \le f(x, y) \le T, \\ 1 - \dfrac{1}{2}\left|\dfrac{f(x, y) - m_2(T)}{C}\right|^{\alpha}, & T \le f(x, y) \le L, \end{cases} \tag{1}$$

where constant C is the normalization factor, T is any one of the K thresholds, and m_1, m_2 is the average gray value of two types of pixels, which can be estimated from both sides of T in histogram $h(g)$:

$$\begin{aligned} m_1(T) &= \frac{\sum_{g=0}^{T} gh(g)}{\sum_{g=0}^{T} h(g)}, \\ m_2(T) &= \frac{\sum_{g=T+1}^{T} gh(g)}{\sum_{g=T+1}^{T} h(g)}. \end{aligned} \tag{2}$$

α is the compactness parameter of the mean value of the element pair within the class, which can describe fuzzy semantics such as approximate, close, and similar, $\alpha \ge 0$.

(3) Designing fitness function. The mask selects the following two energy functions:

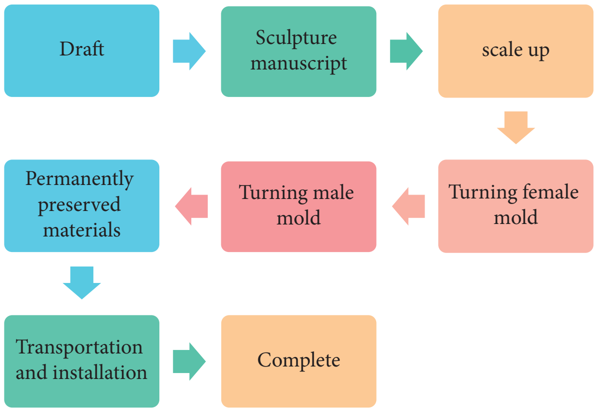

FIGURE 1: Sculpture-making process under traditional technical conditions.

$$E_1 = \sum_{x=1}^{M}\sum_{y=1}^{N}\sum_{l=-d}^{d}\sum_{k=-d}^{d}\left[u_2(x,y) - u_2(x+l,y+k)\right]^2,$$
$$E_2 = \sum_{x=1}^{M}\sum_{y=1}^{N}\sum_{l=-d}^{d}\sum_{k=-d}^{d}\left[u_2(x,y) + u_2(x+l,y+k) - 1\right]^2, \tag{3}$$

where E_1 is a consistency measure, and the smaller E_1 is, the closer the membership values of adjacent pixels with respect to the same class. E_2 is a measure of mutual exclusion. The larger E_2 is, the greater the difference between the membership values of adjacent pixels with respect to different classes.

Horizontal filtering, vertical filtering, downsampling, upsampling, and difference calculation are all part of the Laplacian algorithm. Vertical filtering includes adding horizontal boundary padding and vertical filtering, whereas horizontal filtering includes adding vertical boundary padding and horizontal filtering. Each row's two padding elements are calculated from four elements of their neighboring peers, and the process is independent and irrelevant with good parallelism. After padding is applied, the 1 $*$ 5 calculation window is shifted backward one bit at a time, and the values of five elements in one row are used to calculate the target value corresponding to the window's central element in the target matrix. Each window size's element calculation is relatively independent, resulting in good parallelism.

As shown in Figure 2, the upsampling is divided into two parts: boundary calculation and body calculation. The boundary value is calculated from the values of its adjacent rows or columns. It moves backward one bit in turn with a window of 1 $*$ 2 size, gets two elements of one row at a time, and calculates the two-element values of the boundary row of the target matrix. Actually, the first element value is directly filled, and the second value is calculated from the two values obtained. If the number of rows is odd, it is necessary to calculate the boundary value of the first row, and the rest of the row can be filled with the main body.

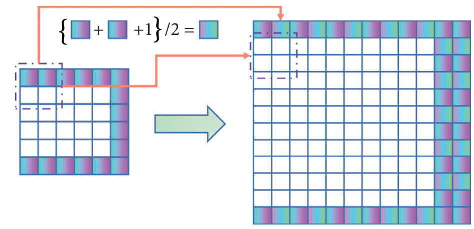

FIGURE 2: Upsampling process.

If the number of columns is odd, only the value of the last column needs to be calculated, and the rest is filled by the main part. Subject: moving back one bit by row and column in a window of 2 $*$ 2 sizes, obtaining four elements of the source matrix each time, and calculating the values of four elements of the target matrix.

The model coordinate system and image projection in the virtual space are transformed into the geometric transformation of the camera coordinate system. Camera pose estimation is to calculate the pose of the mobile phone camera in real time, and the initial matching point set is obtained after obtaining the feature matching of the above-mentioned image and the identification image.

With homography matrix transformation, the reversible transformation from real projective plane to projective plane, this mapping can be expressed by matrix multiplication:

$$P = A \times W \times M, \tag{4}$$

where P represents the coordinates of the two-dimensional image; A represents the camera parameter matrix; W stores the camera's internal parameters; M is the coordinate of the three-dimensional world.

W consists of two parts: the physical transformation of the object plane for positioning observation and the projection R, T of the parameter matrix in the current camera. $[R \mid T]$ is a 3×3 matrix, and the world coordinate system is transformed into the camera coordinate system. The corresponding projection transformation relation is as follows:

$$W = [R \mid T]. \tag{5}$$

The world coordinate system and camera coordinate system used by the Unity3D rendering engine are both left-handed coordinate systems. On the android platform, JAVA and C# methods are called each other through Android JDK, and the camera pose parameters of the parameter matrix R and T are transferred from Android to Unity3D so as to realize the tracking registration of the virtual model from 2D to 3D.

In this way, the algorithm as a whole will have a conditional judgment for one row, which contains a conditional compilation for the last column parity judgment; the last line contains a conditional compilation judgment, which contains a conditional compilation for the last column of parity judgment; partial calculation includes a conditional compilation of parity judgment for the last column.

SIMD (single instruction multiple data) is an instruction to operate multiple data. It is an extension of the basic instruction set of the CPU. It is mainly used to provide fine-grain parallelism, that is, the parallel operation of small pieces of data.

In view of the simplicity of the Laplacian algorithm here, this part is combined with vertical filtering, which reduces the calculation of some data. While optimizing SIMD of vertical filtering, the data needed for downsampling are directly reserved. There are a lot of shift operations in the improved algorithm, all of which use a shuffle instruction to align data. The upsampling algorithm is not suitable for SIMD optimization because of its many judgment conditions.

4. Result Analysis and Discussion

Traditional sculpture is taken as an example for developing a traditional sculpture image recognition system. the mobile device's camera is initialized, keyframe photos of the real scene are obtained, feature points are matched to identify feature images, the mobile terminal's pose is estimated, the spatial distance is calculated between the virtual model and the real scene, and superimposed on the current window to generate the virtual model's fused output. Figure 3 shows a comparison of the effects of various feature detection algorithms.

Other methods are likely to have a large number of features, slow calculation speeds, and a limited number of feature extraction speeds. The algorithm described in this paper has a faster calculation speed and a higher recognition efficiency of feature points, making it suitable for displaying complex textures of traditional sculptures on mobile devices. The algorithm detects local features with a high recognition rate and a high tolerance for light, noise, and small visual angle changes. Furthermore, this algorithm's feature distribution has more correct areas, and the matching accuracy is relatively high. The improved feature matching algorithm of this algorithm performs better in real time and high-efficiency systems.

In the image segmentation method based on basic GA, nine traditional sculpture images of 191×257 are segmented by setting different segmentation parameters. Figure 4 shows the corresponding relationship between parameters and images.

As can be seen from Figure 4, the size of the cluster has a great influence on the segmentation effect and the computer time consumed by image segmentation. The larger the population, the better the segmentation effect, and of course, the more computer time it takes. Search algebra also has a great influence on the segmentation effect. The more search algebra, the better the segmentation effect. However, the search algebra has little influence on the computer time consumed by segmentation; so in order to improve the segmentation effect without consuming too much computational time, the search algebra can be increased. The number of variations has little effect on the segmentation effect, and it also has little effect on the computer time of image segmentation.

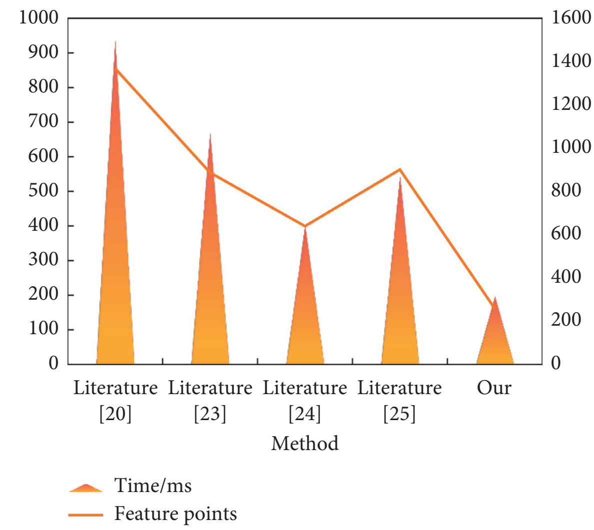

Figure 3: Effect comparison of different feature detection algorithms.

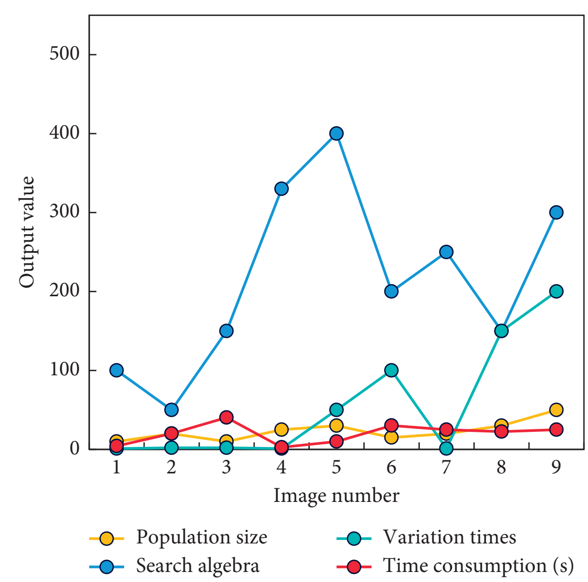

Figure 4: Segmentation result.

The adjustable parameters of the GA segmentation method based on the fuzzy membership surface include population size, mutation times, search algebra, and fitness function parameters. Next, by setting different parameters, the image is segmented, and the segmentation results are compared. The corresponding relationship between parameters and images is shown in Figure 5.

It can be seen from Figure 5 that the size of the population has a great influence on the segmentation effect and the computer time spent on image segmentation. The larger the population, the better the segmentation effect, and of course, the more computer time it takes. Search algebra also has a great influence on the segmentation effect. The more search algebra, the better the segmentation effect. However, the search algebra has little influence on the computer time consumed by segmentation; so in order to improve the

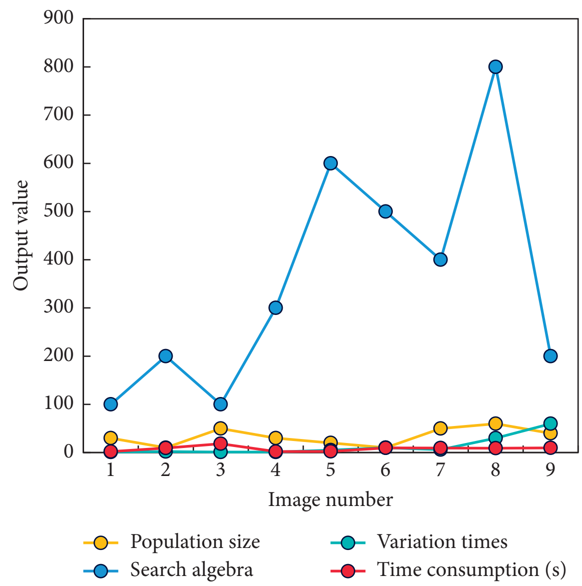

Figure 5: Segmentation result.

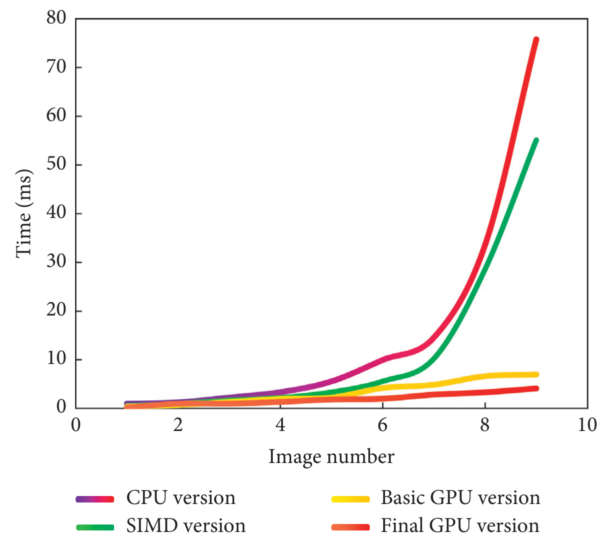

Figure 6: Performance comparison of optimized GPU versions.

segmentation effect without consuming too much computational time, the search algebra is added. The number of variations has little effect on the segmentation effect, and it also has little effect on the computer time of image segmentation.

The Figure 6 shows the performance comparison among the CPU (central processing unit) version, SIMD optimized version, basic GPU (graphics processing unit) version, and optimized GPU version of the Laplacian algorithm.

It can be seen from Figure 6 that as the image size continues to grow, the acceleration ratio also increases. Therefore, it can be seen that using the SIMD optimization technique to optimize the CPU serial code is significant for improving algorithm performance, and it is a very effective optimization method.

The performance comparison between the optimized version of GPU and the basic version of GPU will be compared in detail in the performance improvement chart brought by the following optimization methods. Here, in order to show the acceleration of GPU relative to the CPU version, the performance improvement of the optimized version of GPU for the basic version of GPU is not obvious.

The main feature of geometric sculpture is that its modeling is mainly geometric figures. In 3D software, it is the modeling obtained by adding or subtracting figures through the Boolean operation. Although geometric sculpture is not as rich in surface changes as other shapes, it gives people a simple and straightforward feeling with its unique and minimalist shape.

Structural sculpture mainly emphasizes the structure of works, which is its external manifestation and also the embodiment of its essence and spirit. Usually, the structure is not only the support but also the main component of the enriching sculpture form, and its change will directly affect the change of the sculpture shape. In many art exhibitions, you can see many structural sculptures with rich changes and aesthetic feelings.

The boundary padding part is integrated with the horizontal filter kernel, and the horizontal filter kernel is optimized by combining boundary optimization, conditional compilation, and vectorization. The performance results are shown in Figure 7.

As can be seen from Figure 7, with the increase of the image size, the acceleration ratio greatly increases, and the acceleration ratio is between 14 and 173.

An improvisation is a form of entertainment for artists, as it allows them to express their innermost feelings as quickly as possible. It is a dialogue between mind and matter, as well as a state of selflessness, that is embodied in sculpture creation. The characteristics of the object are conformed and caught, the “truth” of the object lurking in the depths are dig out, and finally, the work is completed according to the original characteristics of creative materials. This method of creation necessitates the author’s artistic ability, as well as keen insight and judgment, and the process of creation is the process of conforming to “God’s will” and gradually releasing it from mixed purity. Because the scheme is uncertain, each step is the work’s birth process, and each step gives the creator a new feeling.

Figure 8 shows the performance improvement of the upsampling algorithm after kernel fusion, conditional compilation, and boundary processing optimization. It can be clearly seen that with the increase of the image size, the speedup ratio increases greatly.

The choice of technical means will undoubtedly affect the presentation form of sculpture works, as sculpture is an artistic form expressed by modeling features. We can only deal with the sculpture language and then express artistic ideas using certain technologies. Many sculpture creators nowadays use the pursuit of pure art as an excuse to avoid personally participating in the technical work of sculpture, believing that as long as the artistic conception is presented by themselves, it is regarded as their own creation, regardless of who provides the technical work or what kind of technology is used to complete it. As a result, once technological

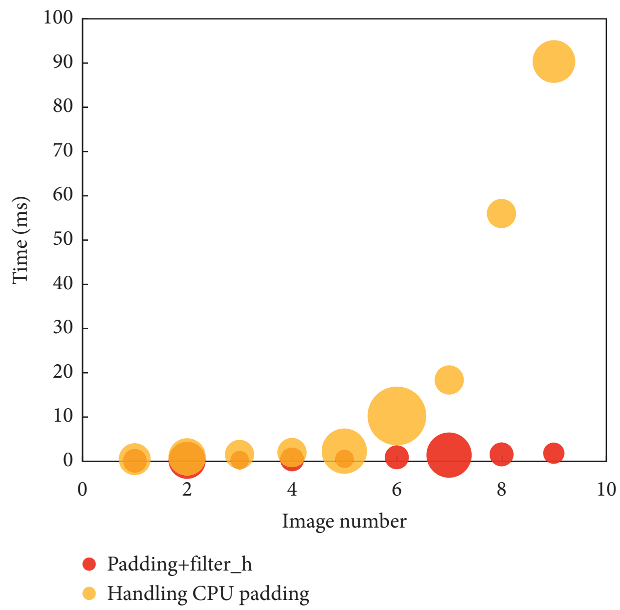

Figure 7: Performance comparison of boundary padding and horizontal filter kernel before and after optimization.

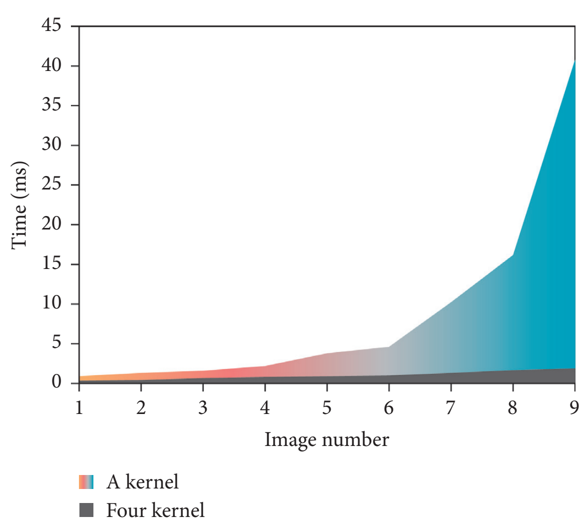

Figure 8: Upsampling optimization performance comparison.

research has progressed to a certain point, digital sculpture creation requires the guidance of artistic theory and artistic achievement, as well as the coordinated development of technical means and artistic achievement so that it can not only demonstrate technology but also create artistic works that shock the soul.

Figure 9 shows the performance of several optimization methods with obvious performance improvement for the basic GPU version. This section gives the performance comparison data of vertical filtering and downsampling after partial optimization.

From Figure 9, it can be seen that vertical filtering and downsampling are used to optimize by processing four columns at the same time, which can improve the distinguishable performance. It can be seen that the simplified

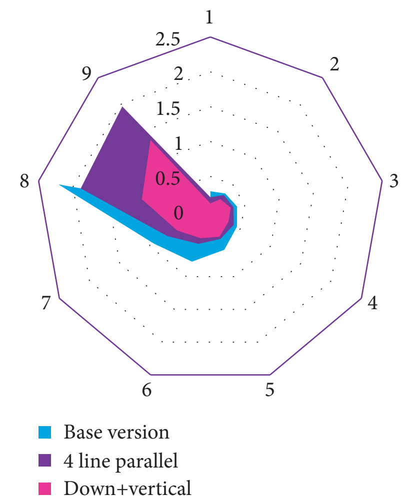

Figure 9: Performance improvement brought by the optimization method on GPU.

algorithm is indeed helpful to performance optimization, but it is not the bottleneck problem of the algorithm performance and has limitations on the optimization effect of the algorithm. Adding the optimization method of padding does not improve the performance, but it does enable the GPU kernel to handle input images with more diversified sizes, and the performance will not be reduced by adding conditional judgment, which theoretically optimizes the algorithm in the process of improving the algorithm.

Digital modeling technology participates in sculpture design and production. Although it has brought a more efficient way of creation to sculpture art and some negative effects to traditional sculpture art, as long as the new technology is treated calmly and used, the development of sculpture art will be promoted.

Some people who have not received professional sculpture training can also use software to make sculpture-like shapes, but such shapes lack the language features that sculpture should possess and reflect through professional knowledge. After all, a pile of mud made by people without professional knowledge in sculpture art cannot be called "mud." The sculpture is called art because it has thresholds and requirements.

5. Conclusion

Three-dimensional technology provides a new carrier for sculpture creation, and sculpture works are displayed in electronic display instruments through electronic information technology, which just promotes the development and spread of sculpture culture and the development and progress of the whole sculpture creation industry. Software belongs to software thinking. Therefore, in artistic creation activities, the creator's thinking is the main guide, supplemented by software thinking. Dealing with the interaction between the two will make artistic creation more efficient, provide artists with modeling forms beyond their own thinking limits, bring new thinking enlightenment, and stimulate artists' creative ability. This paper discusses the method of GA in image restoration processing, and the experimental results show that the image restoration processing method based on GA can improve the image resolution and quality. Future works will continue to solve the problem of matching recognition between traditional sculpture art and the human face. By recognizing facial expressions, we can display different mask expressions with rich cultural connotations and further improve the mobile terminal to add new functions in displaying other interactive experiences of traditional sculpture art.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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Research Article

Research on Cross-cultural Text Reconstruction of Urban Publicity Translation Based on Computer Corpus

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Urban publicity translation, as a cross-cultural communication activity, should aim for communication, employ various translation strategies, adapt to the target language's expression habits, overcome cultural differences, and make the translation easy to accept for target readers. In order to achieve the goal of external promotion, publicity texts should respect and conform to the target culture's language expression as well as the psychology of the audience during the initial stage of urban publicity translation. This paper analyzes the causes of cultural vacancies in the translation of urban publicity materials, starting with the classification and sorting of cultural vacancies in the translation of publicity materials. This paper focuses on using a computer corpus to reconstruct cross-cultural text for urban publicity translation. An automatic corpus expansion method combined with the EM (expectation-maximization) algorithm is proposed to solve this problem. The model is iteratively trained after the generated single corpus is combined with the original data set to create a parallel corpus. Finally, as another important feature of words, the word cooccurrence degree is incorporated into the interword relationship extraction model to create a new word translation evaluation index. Finally, the experiment demonstrates that the EIWR (extraction of interword relations) has higher accuracy than the VSM (vector space model).

1. Introduction

The external image of a city is a comprehensive material and cultural impression that the city shows to the public, and it is an important part of the city's competitiveness. With the continuous improvement of China's international influence and economic strength, China has closer ties with other countries. As an important means of foreign communication, the translation of city publicity is an important means to show the traditional culture, regional features, and development characteristics of the region to the international community, and plays a vital role in improving the image of the city, enhancing the international reputation and strengthening the opening to the outside world [1]. In recent years, scholars at home and abroad have increasingly studied the translation of urban publicity, and the translation of urban publicity has made great progress.

Corpus linguistics is a new interdisciplinary field that combines linguistics, computer science, applied linguistics, and cognitive linguistics. It is still in its early stages of development. Corpus linguistics uses actual language facts as the research object and performs macroscopic and microscopic, qualitative and quantitative statistics and analysis on a large number of corpora using computer tools, revealing the objective laws of language use and the complexity of natural language [2, 3]. The parallel corpus has strong text alignment and high translation accuracy because it is made up of source language texts and translated texts that correspond to the source language texts. However, the parallel corpus's construction costs are high, and parallel corpus resources are scarce and difficult to come by, making it difficult to cover all fields of research. At the same time, the artificial translation quality has a significant impact on translation accuracy [4]. China is a vast country with many ethnic groups, and each region has its own distinct local characteristics and national culture. Chinese cities want a place on the international stage, and language texts are particularly important when they show their own culture and characteristics to foreign audiences [5, 6].

Many different types of corpora have been built and used in the past, depending on the purpose and nature of the corpus. A Chinese-English parallel corpus, as well as an analogy corpus [7], were used in this study. This paper proposes a model training method combined with the EM(expectation-maximization) algorithm to solve the problem of cross-cultural text reconstruction in urban publicity translation. The joint EM optimization method is used to learn translation models from source language to target language and from target language to source language and to complete the bilingual dictionary extraction based on the word relation matrix. Finally, experiments are used to verify the feasibility of this extraction method, which is compared to VSM (vector space model), and the impact of variables such as context window size, corpus size, dictionary size, and word frequency on the final experimental results of the two models is examined.

2. Related Work

The translation is a medium form of cross-cultural communication, and publicity is a cross-language and cross-cultural information exchange and communication with nations, regions, and countries as the main body. The essence and basic task of urban publicity translation are cross-language and cross-cultural information dissemination, which is an important way of external communication [8, 9]. If a city wants to go global, it must first create an international environment conducive to city publicity, which will be recognized and supported by the international community. Literature [10] clearly puts forward the stage theory of urban publicity translation, that is, in the first stage, due to the dominant target language culture, the purpose of publicity is to win the recognition and understanding of the international community, mainly adopting the translation strategy based on the target language; Literature [11] points out that the differences between Chinese and western cultures directly lead to the great differences in vocabulary system and meaning expression between Chinese and English. Because the audience of urban publicity translation is foreign readers, and there are many differences between Chinese and English languages and cultures, it is difficult to achieve the expected publicity effect if mechanical literal translation is adopted. Literature [12, 13] proposed a method of dependency constraint on the target language part of translation knowledge, which effectively improved the translation accuracy. Literature [14] deals with translation knowledge in a semistructured way and proposes an example-based machine translation method. In their experiments, the effect of this method is significantly better than that of a statistical machine translation system. Translation knowledge automatically acquired from corpus usually contains a lot of noise, which affects the translation process. Literature [15] proposes a method to filter monotone combination phrase pairs and a method to filter combination phrase pairs by using a logarithmic linear model.

The subject of translation is the translator, and the translation theory of urban publicity places higher demands on translators. Not only linguistic equivalence but also cultural equivalence and communication equivalence should be considered when translating publicity texts. With the help of the concept of intermediate language, literature [16] proposes a many-to-one translation mechanism. These methods solve the problem of data sparsity, but they also complicate the model and increase the training costs. By introducing tags into the input, literature [17] proposes a method of training translation models. Despite improvements in training efficiency and translation performance, data scarcity remains a problem. Literature [18] proposes a multilingual translation model with an incremental self-learning strategy, which solves the problem of data scarcity by generating pseudobilingual data automatically, but the pseudobilingual data may have noise issues, lowering translation quality. The cooccurrence rule of words in the target language in both parallel and comparable corpora is essentially the same as in the source language, according to the literature [19]. The calculation assumes a one-to-one correspondence between the words in the source language and the target language text. According to the literature [20], a third-party intermediate language could be used to complete the construction of a bilingual dictionary. Its basic concept is to use a common intermediate language, such as English, and a multilingual vocabulary to first translate source-language words into intermediate language words, and then to translate the translated intermediate language words into target language words using the vocabulary to complete the construction of a bilingual dictionary. According to the literature [21] there is a random translation matrix from the source language to the target language, which can translate the source language to the target language, assuming a one-to-many relationship in translation. The local ambiguity problem is solved by this method, but the global ambiguity problem is not. Literature [22] proposes a dependency tree-based method for completing the construction of a context vector and extracting bilingual dictionaries. Literature [23] proposed a method for extracting parallel resources from comparable corpora based on document-level alignment. The basic idea is to use alignment information instead of word context information.

3. Research Method

3.1. Selection and Design of Translation Model for Urban Publicity. The translation of urban publicity is aimed at foreign readers, so that foreign readers can understand and accept the information conveyed by China. In the process of urban publicity translation, the common problems are that translators lack awareness of cross-cultural communication, do not know enough about the thinking patterns of foreign audiences, and cannot translate according to the thinking habits of target audiences. To solve this problem, literature [24] puts forward the principle of "three closeness" in the translation of urban publicity, that is, "the translation of urban publicity should be close to the reality of China's development, the needs of foreign audiences for Chinese information and the thinking habits of foreign audiences".

To maximize the cross-cultural communication effect of urban publicity translation, it should follow the principle of "communication priority" and begin with the foreign audience to truly understand and accept cross-cultural information. In this paper, powerful models are not required for initialization training, but there are two popular models: statistical machine translation and neural machine translation. Because the neural machine translation model is prone to overfitting when the data is sparse, it performs worse in low-resource situations than the statistical machine translation model. The transformer model [25], whose structural design is shown in Figure 1 was chosen among many neural machine translation models for this study.

In this paper, two transformer models in opposite directions are initialized and pretrained, that is, one-way tasks from the source language to the target language and one-way tasks from the target language to the source language.

The pretraining process is completed by the traditional method based on the maximum likelihood principle. The general approach of this method is to maximize the logarithmic conditional probability of correct translation, give the model parameter θ of the source language sentence, and its goal is to get θ^* which satisfies the following formula:

$$\theta^* = \arg\max_{\theta} \sum_{i=1}^{N} \sum_{j=1}^{|t_i|} \log\ p\left(t_{i,j} \mid t_{i,0\longrightarrow j-1}, s_i\right), \tag{1}$$

where N is the scale of training corpus, $|t_i|$ is the length of the target language sentence t_i.

After pretraining, the iterative training process of the model is carried out. Given the original parallel corpus (real corpus) $D = \{S_i, T_i\}_{i=1}^{N}$ and the target language monolingual corpus $T' = \{t_i\}_{i=1}^{P}$, the training goal of the model is to maximize the possibility of bilingual data and monolingual data, namely

$$L^*\left(\theta_{S\longrightarrow T}\right) = \sum_{i=1}^{N} \log p\left(t_i|s_i\right) + \sum_{i=1}^{P} \log p\left(t_i\right), \tag{2}$$

where the first part represents the conditional probability of generating the target language T for the source language S; the second part represents the language model of T, whose main function is to maximize the possibility of sentences.

The degree of vocabulary variation is defined as the number of different words in a given length corpus that reflect the diversity of vocabulary. The number of different words is referred to as the shape symbol number, whereas the number of different word shapes is referred to as the class symbol number. The amount of information and difficulty of a text can be reflected in lexical density. The higher the vocabulary density, the more meaningful words there are, and the more information and difficulty the text contains. The lower the vocabulary density, the less information the text contains and the easier it is to understand. The purpose of calculating instance similarity is to determine the degree of similarity between the source language phrase of the translation instance pair and the input sentence phrase fragment. The expression form of the translation instance is closely related to the similarity judgment. Language surface matching is a type of character-based matching. Two parts to be matched are treated as strings in this method. In general, it only takes into account the length of common substrings in two strings, and the common substrings must be ordered.

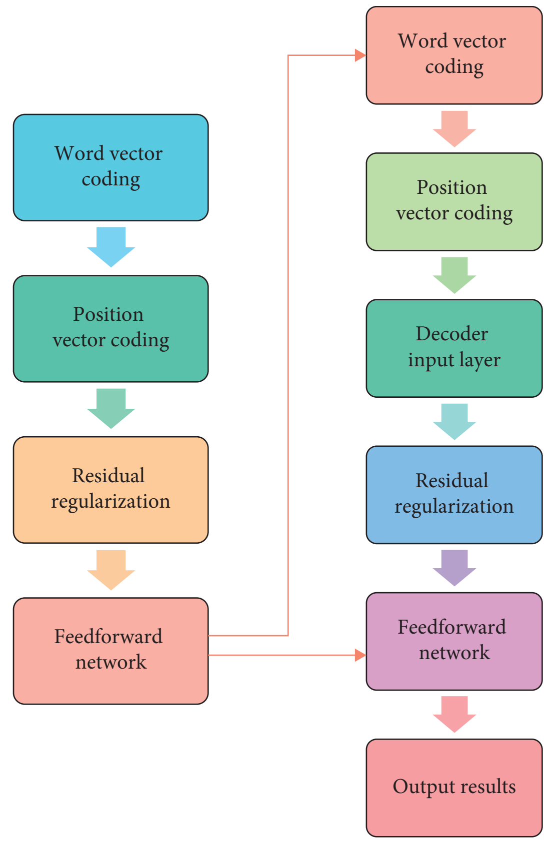

Figure 1: Transformer model architecture diagram.

Among the algorithms based on character matching, the method of editing distance is the most widely used one. This method can be used to calculate the minimum cost $D(m, n)$ of transforming from one string $S = s_1, s_2, \ldots, s_m$ to another string $T = t_1, t_2, \ldots, t_m$.

The algorithm is based on a dynamic programming algorithm, and its complexity is $O(m * n)$. The following are the core parts of the algorithm:

$$D(i, j) = \begin{cases} 0, & \text{if } i = j = 0, \\ D(0, j-1) + w\left(t_j\right), & \text{if } i = 0, j! = 0, \\ D(i-1, 0) + w\left(s_i\right), & \text{if } i! = 0, j = 0, \\ \text{Min}\begin{bmatrix} D(i-1, j) + w\left(s_i\right) \\ D(i, j-1) + w\left(t_j\right) \\ M(i, j) \end{bmatrix}, & \text{other}, \end{cases}$$
$$M(i, j) = \begin{cases} \text{Max}\left(w\left(s_i\right), w\left(t_j\right)\right), & s_i \longrightarrow t_j, \\ 0, & s_i = t_j. \end{cases} \tag{3}$$

Among them, the three transformation operations are replacement, insertion, and deletion. $w(t_j)$ is the cost of inserting t_j , $w(s_i)$ represents the cost of deleting s_i in S, and $\mathrm{Max}(w(s_i), w(t_j))$ represents the cost of replacing s_i with t_j.

In word-based matching, matching is investigated in terms of words. Because the semantics of words should be considered, semantic dictionaries play a very important role. Commonly used semantic dictionaries include WordNet and synonym word forest. In English, apart from semantic dictionaries, word-building analysis is usually required.

At the same time, in order to reduce the workload of the algorithm, a stoplist is often used to filter out these words. Then, judge the similarity between sentences according to the remaining meaningful words. There are many kinds of VSM, among which the most well-known one is $tf - idf$ value.

3.2. Cross-Cultural Text Reconstruction of Urban Publicity Translation. The ideal state of translation is to be able to translate word for word along with the original text. However, in the translation of urban publicity, this situation is very rare. Because English is hypotaxis structure and Chinese is parataxis structure, the two languages are completely different in writing structure and writing habits and are difficult to be compatible at the syntactic level. Therefore, in Chinese-English translation, in order to accurately express the meaning of Chinese and achieve good translation effect, the method of "reorganizing the original text" can be adopted, reasonably change sentence patterns or adjust word order in some parts of the original text, and if necessary, can "reinvent the stove" and reintegrate to reduce the influence of Chinese grammar and sentence patterns, so as to make the translation richer in English charm.

Translators must explore the cultural differences between English and Chinese and cultivate a cross-cultural perspective when working on translation projects. Translators must be culturally aware, observe idiomatic expressions and thinking differences in English, use English expression habits and thinking styles, and cannot create words out of thin air or break the horizontal combination relationship between words and words. They should take responsibility for themselves, their culture, and the target language users in translation, as well as contribute their own efforts to help foreign friends and export China's excellent culture. In general, a single word cannot express a complete theme, it must be combined with other words to do so. Different words are combined to express various theme contents. This word combination reflects the semantic information of words as well as the correlation between them. Because only nouns, verbs, adjectives, and adverbs in comparable corpora are studied in this paper, the corpus must be preprocessed.

In this paper, based on the selection rules of seed word pairs, the seed dictionary is extracted from the general dictionary, but the uniqueness of words in the seed dictionary needs to be ensured in the process of mapping relations between words, so this paper adopts certain selection rules to extract seed word pairs from the general dictionary, among which the selection rules of the seed dictionary are shown in Figure 2.

In this paper, the words with low similarity in the source language are selected first to ensure the differentiation of the correlation between words in the seed dictionary, among which is the formula for calculating the similarity of words in the source language.

$$S\left(W_{s_i}, W_{s_j}\right) = \sum_{1<k<m} V_{s_{ik}} \times V_{s_{jk}}, W_{s_i}, W_{s_j} \in \text{Set}. \quad (4)$$

In the formula, V_s represents the word vector of the word, k is the component of the k-th dimension in the word vector, and m is the dimension value of the VSM trained word by the source language corpus.

If the frequency of the word W_{t_i} in the target language corpus is too low, the relevance with the target words will be lower, which can not reflect the relevance between the words in the target language. If the frequency of W_{t_i} is too high, it may be related to the words in the whole target language corpus, which can not achieve the purpose of taking the relationship between words as an important distinguishing feature of words.

Therefore, if the word frequencies are the same, the word pairs with the smallest index value are selected according to the index values in the dictionary, and if the number of selected word pairs can not meet the calculation requirements, then the word pairs are selected from low frequency to high frequency.

In this paper, the correlation between a word and other words is regarded as an important distinguishing feature of the word, and the correlation is quantified by the similarity of word vectors. The construction of the interword relationship matrix is completed by the seed dictionary, and at the same time, the correlation between the interword relationship VSM of the source language and the interword relationship VSM of the target language is also completed. The specific steps are shown in Figure 3.

Firstly, the rules are extracted from the general dictionary through the seed dictionary, and the seed dictionary is extracted. The number of seed word pairs is N, and the seed set formed is expressed as $\left\{W_{s_i}, W_{t_i}\right\}, i \in \{1, 2, \ldots, N\}$, W_s is the source language word, W_t is the translation word corresponding to W_s in the target language, and i is the index value of W_s in the seed dictionary.

Then, the correlation degree between each word in the source language and the words in the source language in the seed dictionary is constructed by the word vector. For the quantification of the correlation between the unknown word W_{s_x} and each word in the seed word set, this paper adopts the calculation method of vector inner product

$$M\left(V_{s_x}, V_{s_i}\right) = \sum_{1<j<m} V_{s_{xj}} \times V_{s_{ij}}, i \in \{1, 2, \ldots, k\}. \quad (5)$$

In the formula $V_{s_i} \in \left\{V_{s_1}, V_{s_2}, \ldots, V_{s_k}\right\}$, $V_{s_{xj}}, V_{s_{ij}}$, j represents the component of the j-th dimension of the word vector V_{s_x}, V_{s_i}.

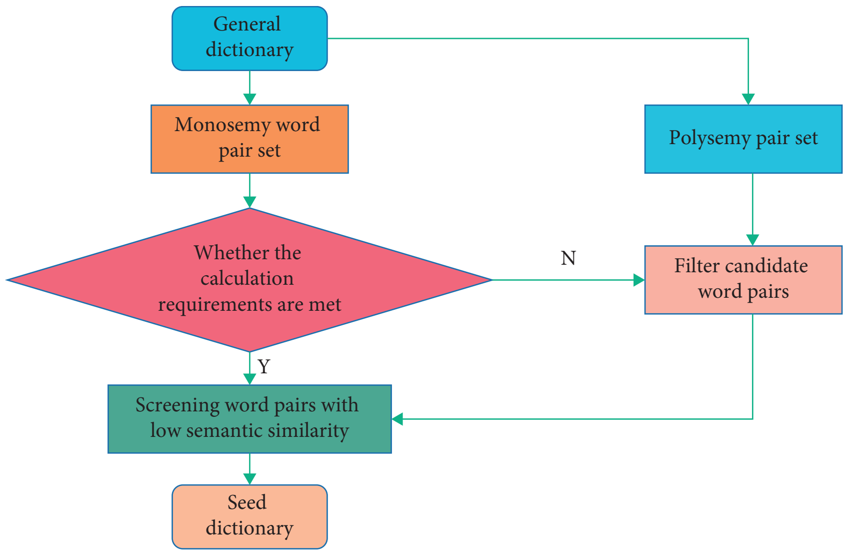

Figure 2: Seed dictionary extraction rules.

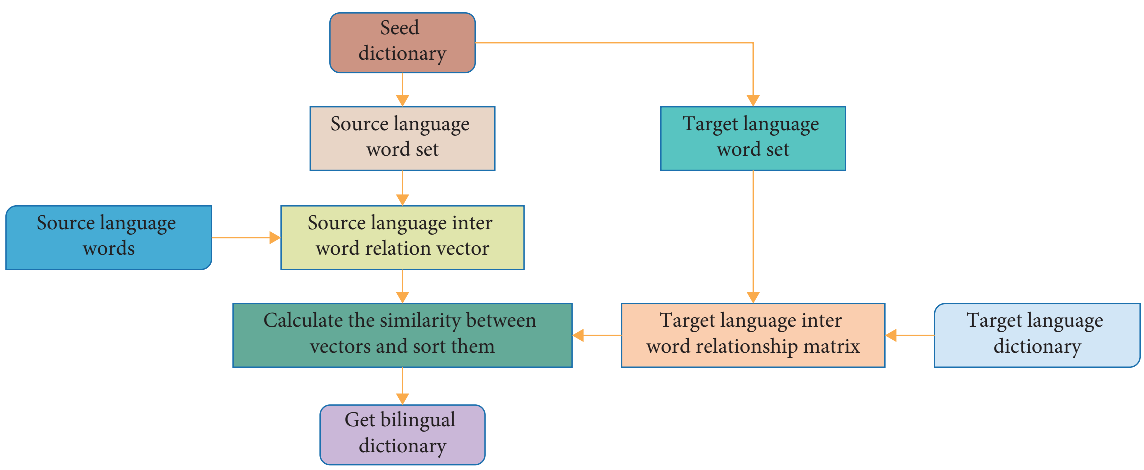

Figure 3: Extracting bilingual dictionaries based on the relationship between words.

Finally, the cosine similarity is used to calculate the relation vector between two words, which can be expressed as

$$S\left(V_{m_s}, V_{m_t}\right) = \frac{\sum_{1<i<k} V_{m_{si}} \times V_{m_{ti}}}{\sqrt{\sum_{1<i<k} V_{m_{si}}^2 \times V_{m_{ti}}^2}}. \quad (6)$$

The translation appears to be a process of changing one linguistic sign to another, but in reality, it is a cross-language and cross-cultural communication activity. As a result, translation is more than just a language conversion; it is also a social and cultural transformation process. Different scholars advocate for various translation standards and methods in the translation process, and various translation methods and standards have reached a theoretical level. The original text has more nouns and adjectives than the translated text, but the latter has slightly fewer verbs and adverbs. The difference in vocabulary density between the two subdatabases can be attributed to a large number of nouns and adjectives in the original text.

4. Results Analysis and Discussion

4.1. Comparison of Parameters and Results. In this paper, the transformer model is used as the baseline model of translation training. After several rounds of parameter combination optimization, the relevant important parameters of the transformer model are set in the experiment to achieve the best performance of the model.

In order to explore the corpus generation of the new method in this paper in more detail, according to the convergence of the iterative model of EM algorithm, Figure 4 shows the curve of the performance of the model changing with each iteration process from different translation tasks.

As can be seen from Figure 4, when the EM algorithm is iterated for 10 times, it tends to converge, and the performance of the model is hard to be improved, which also proves that the method in this paper makes the model tend to be stable after a certain iteration process.

Different versions are born as a result of the subjectivity of the translators. The translator's cultural mentality is full of contradictions, both submissive and treacherous, in the translated text. As target readers, it may be difficult to imagine the translator's confusion and cultural references in the translated text. The cultural oddity in the translation demonstrates that the target readers generally lack the background knowledge necessary to appreciate the source culture, and the translator must perform some cultural filtering in order for the translation to be accepted. Figure 5 depicts the relationship between the confusion of generating corpus and the EM algorithm iteration times in order to see the benefits and drawbacks of the transformer model's corpus as the EM algorithm iterates.

As can be seen from Figure 5, after 10 iterations, the confusion of the generated corpus will not decrease significantly, which is consistent with the convergence of the model and avoids the possibility of the model falling into local optimum.

The phenomenon and activity of translation is a cross-ethnic cultural phenomenon and activity. Cultures of different countries are at different stages of development, with different characteristics and cultural positions, due to the imbalance and asymmetry of cultural development. When universal things are localized, they frequently face local opposition, and when local things are globalized, they are often misunderstood or suppressed. More importantly, when different cultures collide and clash, it is difficult to come to an agreement on values, behavior patterns, problem-solving methods, and procedures, and cultural friction or conflict can quickly spiral out of hand, escalating into difficult-to-adjust disputes.

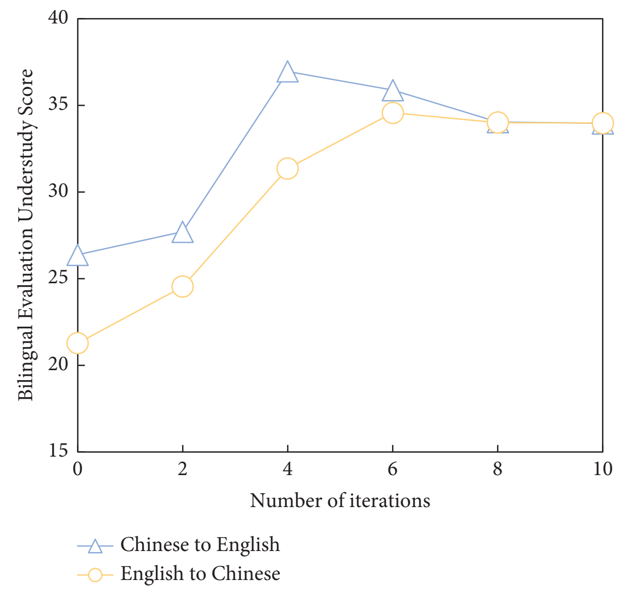

FIGURE 4: Variation curve of model performance.

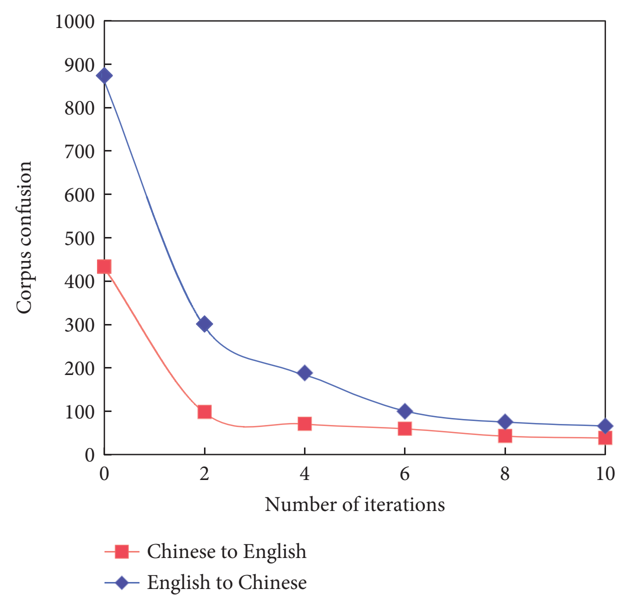

FIGURE 5: Curve of the confusion degree of corpus generated by the model with the number of iterations.

4.2. Corpus-Based Dictionary Extraction Analysis. The translation of urban publicity is like a fish swimming between the ponds of two languages, and this state just provides the prerequisite for cultural hybridity, internalization, transformation, and reconstruction. The essence of translation is to translate meaning. However, the symbols of cultural meaning contained in the source text are the most difficult to control, copy, and reconstruct in the process of translation. Many texts, reluctantly translated, cannot make the target readers feel similar to the source readers. Cultural or aesthetic failure shows that such translation of city publicity is a failure.

The corpus of this experiment is English and Chinese. English-Chinese bilingual dictionaries are extracted with English as the source language and Chinese as the target language. Dictionaries are another important resource of this experiment, including English dictionary, Chinese dictionary, English-Chinese bilingual dictionary, English stoplist, and Chinese stoplist. In the experiment, 10% of words in the English dictionary were randomly selected as the test set, and the corresponding translations of English words were obtained from the English-Chinese bilingual dictionary as the verification set to calculate the accuracy of bilingual dictionary extraction.

Accuracy is the most direct index to evaluate a model. Firstly, this paper compares the overall accuracy of VSM and EIWR (extraction of interword relations), in which the context window size is set to 10, and the experimental results are shown in Figure 6.

From Figure 6, it can be seen that it is feasible to quantify the relationship between words by using word vectors in a comparable corpus and to apply the relationship between words as the extraction feature of words in information extraction.

Whether for VSM or EIWR, the window will affect the expression of word context to a certain extent. For VSM, if the window is too small, the context semantics of the current word cannot be accurately expressed. Therefore, this paper takes the window as a parameter and takes the value of n in P@N as 20 to study the influence of the window on the final

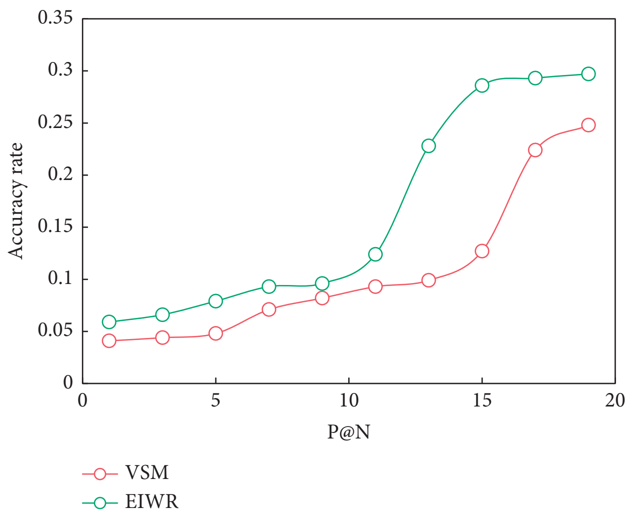

Figure 6: Model accuracy.

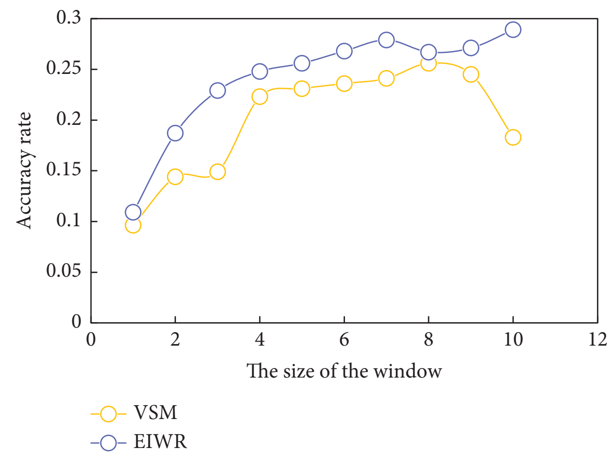

Figure 7: Influence of window on the accuracy of two models.

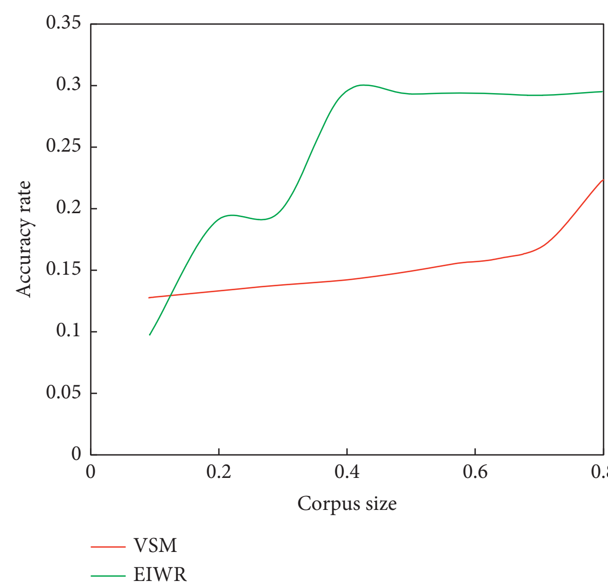

Figure 8: The influence of corpus size on the accuracy of the two models.

extraction effect of the two models. The experimental results are shown in Figure 7.

From Figure 7, it can be seen that the window size has a certain influence on the experimental results of the two models. Especially for VSM, the window size has a particularly obvious influence on the final extraction results. At the beginning of the experiment, the accuracy of VSM is positively correlated with the window size, and when the window size exceeds 10, the accuracy is negatively correlated with the window size, which also verifies the hypothesis that VSM introduces more useless information with the increase of window size.

Experiments show that choosing different sizes of windows in VSM or VSM will affect the final extraction effect, and choosing the correct window value will help to improve the accuracy of bilingual dictionary extraction.

In VSM, the size of the corpus will directly affect the calculation of word frequency and document frequency. In Fan model, the size of the corpus will also directly affect the generation of word vectors, so the size of the corpus will directly or indirectly affect the final dictionary extraction results. Therefore, this paper selects different corpus sizes for experiments. The experimental results are shown in Figure 8.

The experimental results in the graph above show that the corpus size has an impact on the final experimental results of the two models. The accuracy of VSM is higher than that of EIWR in a small-scale corpus, but as the corpus grows larger, the experimental results of EIWR clearly outperform those of VSM. Whether using the VSM or Pa model, the seed dictionary is an important component of bilingual dictionary extraction because it serves as a link between the source and target languages. The effect of seed dictionary size on experimental results is investigated in this paper.

It can be seen from Figure 9 that the size of the seed dictionary has a certain influence on the extraction results of both models, but it is more significant for VSM, and its accuracy is positively correlated with the size of the seed dictionary. On the other hand, it also shows that using a small-scale bilingual seed dictionary in the interword relationship model can achieve higher accuracy and greatly reduce computational complexity.

Figure 10 shows that the VSM is better than EIWR for low-frequency words. However, the accuracy rate of using EIWR for our daily use of high-frequency words has increased from 31.4% to 48.8%, and the improvement effect is obvious, which also shows that the relationship features of our daily use of high-frequency words are more distinguishable than the contextual features.

Accurate comprehension is the foundation of urban publicity translation. It is impossible to talk about style or aesthetic transmission of translation if the meaning is not understood correctly. Information transmission is not automatic or superficial; it necessitates decoding and interpretation. The meaning of reading is directly related to the context in the translation transformation process, and the context plays an important role in the generation of

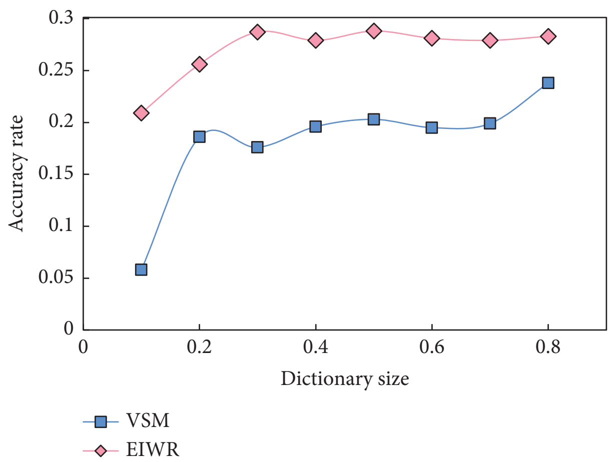

Figure 9: Influence of dictionary size on accuracy of two models.

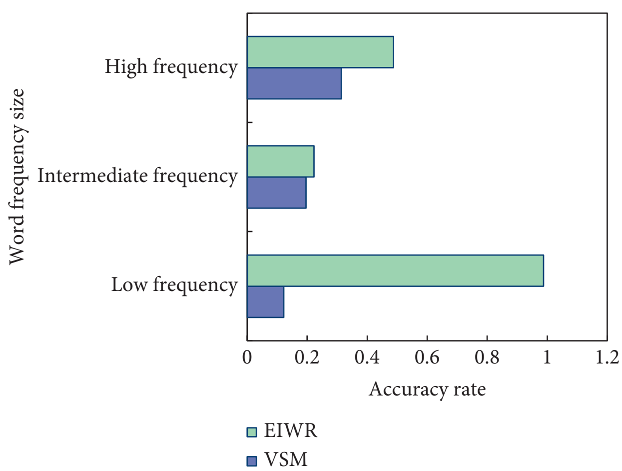

Figure 10: Accuracy of two models with different word frequencies.

meaning. Aside from accurate interpretation, the translated object's publicity effect cannot be overlooked. After analyzing the composition and characteristics of various components in the target language, one of the challenges of urban publicity translation is maximizing their inclusion and synthesis in the target language. The ecological environment, religious beliefs, national customs, aesthetic taste, way of thinking and values, and so on differ between nationalities. The same thing will inevitably produce different associative meanings based on the concept of vocabulary itself under the influence of their own unique cultural traditions. This associative meaning is not always related to the word's actual meaning, but it can evoke a familiar feeling in a particular culture.

5. Conclusion

The translation of city publicity is an important tool for a city to project its image to the rest of the world, as well as a cross-cultural communication medium. Starting with the translation of publicity materials, this paper focuses on using a computer corpus to reconstruct cross-cultural text for urban publicity translation. The two translation models are optimized using a joint EM training algorithm to improve their translation performance. On Chinese-English machine translation tasks, the experimental results show that the machine translation model based on this method outperforms the current popular strong baseline system. Experiments show that the interword relation model, when compared to the basic model, can significantly improve the extraction effect of bilingual dictionaries in comparable corpora, particularly for the translation words of high-frequency words, with an accuracy rate of 48.8%.

The assumption that the correlation between words is symmetrical is used by EIWR, but this assumption does not apply to all situations in real life. If future work can use linguistics' grammar and semantic knowledge to analyze the correlation between words, the relationship between words can be evaluated and quantified more thoroughly, and the final extraction effect can be improved.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author does not have any possible conflicts of interest.

Acknowledgments

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Research Article

Research on the Whole Teaching of Vocal Music Course in University Music Performance Major Based on Multimedia Technology

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MT (multimedia technology) music teaching has changed the rigid, unitary, and boring teaching form of traditional music teaching, which has made a comprehensive breakthrough and impact on traditional university music education and has shown a brand-new teaching form to contemporary college students, greatly increasing their strong interest in learning music. In this paper, an objective evaluation method of vocal music quality based on the comparison of sound parameter characteristics is proposed by using the technology of sound signal parameter analysis and extraction. Through confidence measure, reliable data are selected for online adaptive updating of Gaussian mixture model, and the recognition results are smoothed to further remove the instantaneous mutation error. The main melody of singing is discriminated by fundamental frequency discrimination model. Experiments show that the overall accuracy rate of the main melody of vocal music extracted by this algorithm is 86.24%.

1. Introduction

MT (multimedia technology) is the product of the progress of the times and the demand of educational development [1]. With the development of the times and the progress of science and technology, MT and its related teaching methods have gradually played an increasingly important role in China's higher education system because of their synchronization, integration, and interactivity [2]. Vocal music teachers usually have professional knowledge of music theory but lack systematic computer knowledge. The evaluation of students' singing level is mainly based on their personal experience and feelings, with strong subjectivity. Therefore, it is of great practical and promotional value to study and develop an intuitive and easy-to-operate interactive multimedia vocal music teaching system.

The progression of music art from early concrete music to modern synthetic electronic music to post-modern computer music reflects not only the evolution of the music art form, but also the evolution of music technology [3, 4]. Music education at the university level is an important part of modern education. It not only enriches young students' after-school activities, but also provides them with another professional skill, allowing them to enter society with a skill [5]. The advantages of MT include an intuitive image and strong interaction. Exploring and applying the benefits of MT can help students form scientific sound concepts, improve their intonation and rhythm, cultivate their expressive force in vocal music singing, and create favorable conditions for the formation of their personalized performance style [6, 7]. College vocal music teachers should gain a scientific understanding of the value of MT, find the best combination of technology and vocal music teaching, promote innovation and reform in the vocal music teaching mode, and improve the efficiency and quality of vocal music instruction.

With the continuous development of network technology and information technology, many universities have adopted MT in the course content of auxiliary harmony, solfeggio, impromptu accompaniment, etc., which can show the vocal music teaching process more intuitively, make the teaching content illustrated with pictures, and thus stimulate students' enthusiasm for learning vocal music [8]. In this paper, an objective evaluation method of vocal music quality based on the comparison of sound parameter characteristics is proposed by using the technology of sound signal parameter analysis and extraction. Select reliable data through confidence measure to realize online adaptive updating of GMM (Gaussian mixture model), and get GMM that better matches the audio signal to be segmented, thus improving the recognition accuracy. In the song melody positioning part, based on the difference of timbre between song and accompaniment, the fundamental frequency discrimination model using neural network is added, and the probability that the dominant fundamental frequency track belongs to song melody based on subsection statistics can effectively reduce the false alarm rate of melody positioning and improve the overall accuracy.

2. Related Work

Literature [9] discusses three aspects: the historical evolution of music communication media, the appearance of new audio-visual media competition, and the dominant trend of network music communication. Literature [10] gives appropriate suggestions on the function and selection of modern teaching media. In [11] by comparing with the old standards, this paper analyzes the importance of the requirements of teachers' information and communication technology and cooperation ability in the professional competence standards for primary and secondary school teachers issued by the French Ministry of Education. In [12] by allowing students to actively participate in various music teaching practice activities and respecting their different learning methods and different music experiences formed as an independent individual, students' aesthetic ability can be comprehensively improved, so that students' creative thinking can be fully developed, thus forming their good humanistic quality. Literature [13] regards everyone as an independent individual, encourages students to dare to express their opinions, and encourages students to think creatively. On the basis of the existing theoretical analysis, this paper comprehensively analyzes the principles, learning modes, and implementation methods in the integration of information technology and music curriculum. In [14] according to the current situation that MT is applied to music teaching, through the breadth and depth of multimedia application and teaching results, this paper makes some thoughts and studies on the role and prospect of multimedia in the actual process of music education. Literature [15] points out that the correct use of multimedia teaching means in music teaching is of great significance to the improvement of music teaching theory and norms. Literature [16] studies people's activities in music education from the psychological point of view, including the psychological activities of students in feeling music, expressing music, creating music, learning music knowledge and skills and music culture, and psychological activities in music appreciation, etc., which are found out to guide educational activities. This paper is of great help to the research of music classroom in primary and secondary schools.

Speech plays an important role in modern life as a means of communication. People's demand for speech signal processing technology is growing every day as society and science and technology progress, and it has been vigorously developed, including speech coding, speech decoding, speech synthesis, speech recognition, speech enhancement, and so on. The AR (autoregressive) model is used in [17] to build a model of source signal separation that realizes the separation of single channel source signals. Pitch estimation is used to generate sound music templates in [18]. In [19] the amplitude spectrum of mixed signals is separated into a sparse matrix and a low-rank matrix using the sparsity of speech signals and the low-rank nature of music accompaniment, and then the separation of vocal music is realized using binary templates. The separation of different music signals is extended using nonnegative matrix decomposition. One of the major drawbacks of this method is that it requires a lot of computation and the separated signals are too simple. For nonnegative matrix decomposition, there are also some improved methods and supervision methods. A main melody extraction method based on speech separation has been proposed in [20, 21]. Experiments show that main melody extraction algorithms that include speech separation perform better than those that do not. Literature [22] calculates the saliency function using the source-filter model and harmonic weighting, extracts several candidate melody lines based on melody continuity, and finally locates the song melody and extracts the main melody based on a set of candidate melody line characteristics.

3. Research Method

3.1. Feasibility of Modern MT in Vocal Music Teaching. The ultimate goal of MT in music class is to increase the vitality of college music teaching activities. The multimedia class should be elegant, simple, and convenient to operate, the selection of teaching materials should be scientific and reasonable, other contents that are not helpful to the teaching focus should be stopped, and music content that is helpful but difficult for college students to understand should also be carefully selected.

MT can provide more abundant music information resources for autonomous learning for college students with high music literacy than in the classroom, and MT can provide key technical support for college students to carry out music extracurricular activities and online retrieval, and this type of autonomous learning in spare time is simply an effective extension of college music classroom learning. Students can choose the learning content that best suits them if they are made aware of autonomous learning. Furthermore, multimedia can assist students in learning independently by utilizing its inherent benefits and by providing more comprehensive learning resources. Using MT for music education is a good combination of music instruction by teachers in the classroom and independent learning by students outside of the classroom, and it gradually evolves into a new teaching mode that not only broadens students' horizons but also improves their learning efficiency.

Using MT for music teaching has become an inevitable choice for the change of teaching form, but multimedia is only a tool, which cannot replace teachers' position in the classroom. Therefore, it is necessary to strengthen the training of music teachers' ability to use MT and deepen teachers' understanding of MT and its significance to today's music teaching, not only to let teachers learn how to use MT, but also to make teachers learn how to use MT reasonably, so as to make it a tool to promote music classroom teaching rather than a tool to hinder music classroom teaching process.

Music aesthetic psychology refers to the psychological state and ability of the appreciator in aesthetic activities, including music perception, music thinking, and music emotion. The aesthetic performance is the difference of the appreciator's aesthetic attitude, aesthetic preference, and aesthetic ability. In music classroom teaching, apart from the differences in individual physiological and psychological performance, there are differences in their musical aesthetic psychology. Through the sound level, intensity, and rhythm, intuitively feel the brightness of the object, the ups and downs of modality, and the excitement of feeling. In hearing, the higher the pitch, the higher the sense of space, and the brighter the vision. In a good mood, the individual's active thinking and concentration make students more sensitive to the feeling and discrimination of the basic elements of music.

Multimedia teaching can transform a dull classroom into three-dimensional content, which can pique students' interest in learning by incorporating the vivid design of hearing, vision, and feeling appreciation that textbooks demand. Teachers cannot show concrete objects in areas where teaching conditions are limited, students do not recognize the sound effects of musical instruments in textbooks and pictures, and they are unfamiliar with the customs of a few areas. These difficult multimedia can be presented one at a time to pique students' interest and pique their curiosity, allowing them to appreciate and comprehend more stereoscopically.

From the age of seven to eleven years, they are called the early school age. They are in the specific operation stage, and their unintentional memory is dominant, their intentional memory is gradually strengthened, their memory of intuitive images is stronger than that of abstract logic, and the time of continuous concentration of attention increases with the development of age. The research on memory ratio, as shown in Figure 1, also learns a content. After comparison, it is found that through the combination of audio and video, people can master knowledge more firmly and more efficiently through various senses.

In the stage of formal operation, intentional memory is dominant in middle school students. In attention, they can take the initiative to pay attention according to their own preferences and purposes. With the increase of age, their ability to understand music and control their bodies is enhanced, and their learning efficiency is naturally enhanced. When the knowledge learned is logically arranged across the length of time and presented to the students, the students can absorb it at a glance. The collection and editing of audio-visual materials can enable the teachers to extract the important and difficult points independently and save the time and efficiency of repeated appreciation from the beginning to carry out other teaching activities and improve the teaching efficiency.

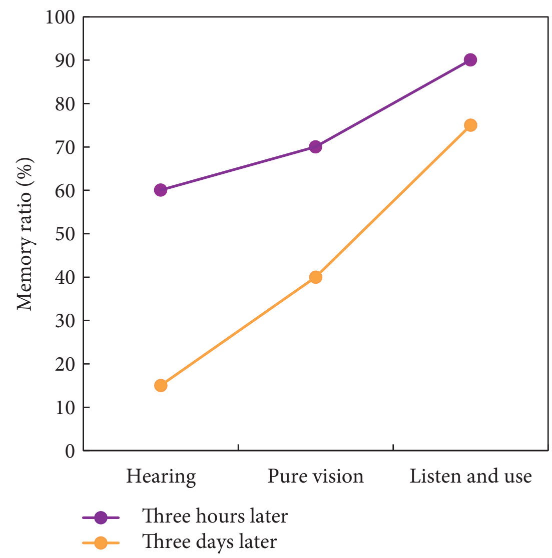

Figure 1: Memory ratio.

Multimedia teaching can provide a good atmosphere for students. Sensory stimulation can make students' music imagination and music thinking active. This environment enables students to follow the teacher's steps. They can also have an epiphany during this period, which is also the sublimation stage of music aesthetics, enabling them to complete the teaching content efficiently.

If teachers make rational use of differences in college students' knowledge structures, carefully set teaching objectives, and create scientific teaching design, it will not only help to promote college students' music learning, but also help college students learn as much about music knowledge as possible in a short class by taking advantage of the cross between disciplines and deepen their understanding of music and related art culture, in order to realize the educative goal.

3.2. MT-Based Holistic Teaching Method of Vocal Music Course for College Music Performance Major

3.2.1. Vocal Music Evaluation Method. The key to the research and development of multimedia vocal music teaching system is to establish the corresponding vocal music measurement method and scoring mechanism. Vocal music scoring is different from voice scoring. The multimedia vocal music teaching system established in this paper adopts the scoring mechanism of standard sound materials [23, 24], and the vocal music singing quality evaluation system using standard sound materials mainly consists of three parts: sound feature extraction, feature parameter matching, and scoring mechanism, as shown in Figure 2.

The corresponding feature parameters are extracted and matched after preprocessing the evaluated singing

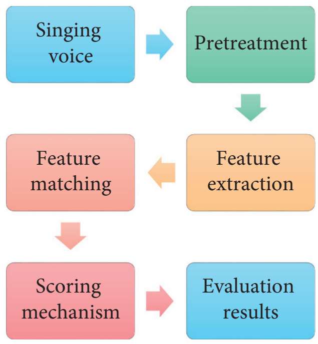

Figure 2: Vocal music evaluation system based on feature comparison.

voice and a standard voice, respectively. The higher the similarity, the higher the score given by the scoring mechanism to the evaluated voice. The volume intensity curve, fundamental frequency trajectory, and breath smoothness are the most important feature extraction parameters. The dynamic time warping method is used to compare similarity in feature matching.

Singing refers to performing activities with human body as sound generator. When singing, human body and spirit should enter and maintain the required state of singing. Correct breathing is the driving force of singing. Therefore, breath plays an important role in singing. The measurement of breath is a process of self-comparison, and the degree of breath stability can be measured by calculating the standard deviation of test sound waveform.

Standard deviation is a measure of the degree of dispersion of a set of values from the mean value. A larger standard deviation means that most of the values differ greatly from their average values, while a smaller standard deviation means that most of the values are closer to the average values. For vector X, its standard variance function $\mathrm{std}(X)$ is

$$\mathrm{std}(X) = \left(\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \overline{x})^2 \right)^{1/2}, \tag{1}$$

where n represents the number of sampling points; $\overline{x}$ represents the average amplitude.

In sight singing, syllables and notes have a one-to-one correspondence. Seven singing names have no zero initial consonant, so the vowels are alternated. The score can be used to determine the roll call of notes, and phonetics knowledge can be used to predict the acoustic characteristics of each phoneme. As a result, note segmentation can be transformed into the following problems if the singer does not omit or add notes:

Given the score sequence M and the singing sequence S, solving an optimal match T between them can minimize the cost function, that is:

$$\arg\min \mathrm{Cost}(T|S, M). \tag{2}$$

Research shows that people's perception of pitch depends on the pitch of the most stable part inside the note. Therefore, the histogram of all sampling points on the pitch curve is taken according to the preset granularity, and the component with the most sampling points in the histogram is taken as the actual pitch of the note. On this basis, the pitch deviation between singing S and reference score M is defined as the average value of the difference between the actual pitch of all notes and the pitch of reference score (after transposition) weighted by the length of notes, namely:

$$\mathrm{pitch\_diff} = \frac{\sum_{i=1}^{N} \mathrm{Dur}_i \times \left|\mathrm{pitch}M_i - \mathrm{pitch}S_i\right|}{\sum_{i=1}^{N} \mathrm{Dur}_i}. \tag{3}$$

$\mathrm{pitch}M_i$ represents the pitch of the i th note in M, $\mathrm{pitch}S_i$ represents the actual pitch of the i th note in S, $Du\ r_i$ is the duration of the i th note, and N is the total number of notes in the song.

Duration accuracy reflects the consistency of note duration in singing. Similar to rhythm, the score does not specify the absolute length of notes, so it is necessary to normalize the length of notes in actual singing by using the beat number of notes in the score. In the concrete implementation, this paper uses the standard deviation coefficient of normalized note duration to measure the duration deviation between score M and singing S, namely:

$$\mathrm{dur\_dev} = \frac{\mathrm{std}(\mathrm{dur}S_i/\mathrm{dur}M_i)}{\mathrm{mean}(\mathrm{dur}M_i)}, \quad i \in [1, N], \tag{4}$$

where $\mathrm{dur}M_i, \mathrm{dur}S_i$ represent the duration of note i in M and S, respectively; $\mathrm{mean}(A)$, $\mathrm{std}(B)$ represent the mean and standard deviation of A, B.

The purpose of vocal music score is to give an objective evaluation of the singer's grasp of the melody of the music, mainly including sound intensity, pitch, and breath. The higher the score, the more accurate the singer's interpretation of the music; the lower the score, the less accurate the singer's grasp of the melody of the music. The scoring formula is as follows:

$$\mathrm{score} = k_1 - \frac{100}{1 + a_1 (\min \mathrm{disv})^{b_1}} + k_2 \frac{100}{1 + a_2 (\min \mathrm{disp})^{b_2}} + k_3 \frac{100}{1 + a_3 (\mathrm{st})^{b_3}}. \tag{5}$$

Among them, $k_1 \sim k_3$ is the weight of each scoring parameter in the scoring mechanism; min disv, min disp are the distance of sound intensity and pitch parameter, respectively; st represents the breath stability parameter. The choice of weights can be adjusted according to different requirements or different scoring priorities.

3.2.2. Extraction of Main Melody of Vocal Music. Melody is the most important musical element, which is composed of single tones with different pitches and durations. The main melody can be divided into vocal melody and general melody. If polyphonic music contains songs, the pitch sequence of songs is considered as the main melody of vocal music. If there is no singing voice, the pitch sequence of the instrumental playing sound dominated by energy is the main melody of the instrumental music.

From the perspective of physics, pitch is determined by fundamental frequency. Based on the characteristics of singing voice, this paper proposes an automatic labeling model (as shown in Figure 3).

Short-term stationarity is a property of music, which means that the signal characteristics are essentially stable over a short period of time. Stationarity can last anywhere from a few hundred milliseconds to several seconds depending on the characteristics of the music signal. The continuous nonstationary signal stream is segmented into a series of short-term stationarity segments, which is known as segment presegmentation.

Segment presegmentation divides the music signal into many segments s_i, $i = 1, 2, \ldots, N$, and assumes that each s_i belongs to either vocal segment or nonvocal segment.

Let $|x_{i,1}, x_{i,2}, \ldots, x_{i,M}|$ be the M-frame feature vector of s_i segment and let $\lambda_v, \lambda_{\mathrm{nv}}$ be the GMM (Gaussian mixture model) of vocal music and nonvocal music, respectively, and the logarithmic likelihood ratio of s_i to $\lambda_v, \lambda_{\mathrm{nv}}$ is as follows:

$$\begin{aligned} \log P(s_i|\lambda_v) &= \sum_{j=1}^{M} \log P(x_i \mid \lambda_v), \\ \log P(s_i|\lambda_{\mathrm{nv}}) &= \sum_{j=1}^{M} \log P\big(x_{i,j} \mid \lambda_{\mathrm{nv}}\big). \end{aligned} \tag{6}$$

If $\log P(s_i \mid \lambda_v) > \log P(s_i \mid \lambda_{\mathrm{nv}})$, then s_i is identified as a vocal category; otherwise it is a nonvocal category.

One of the key technologies for music segmentation is the training of vocal and nonvocal music models. The accuracy of recognition is influenced by the quality of the models. The instruments, playing methods, singers' voices, and vocals are all very different because of the various types and genres of music and songs. As a result, the key technologies for improving segmentation accuracy are reducing model complexity and bringing them closer to each piece of music to be processed.

Amplitude compressed pitch estimation filter is a robust multifundamental frequency extraction method [9, 10]. In this paper, the pitch saliency function is calculated by convolution of logarithmic domain comb filter and logarithmic domain spectrum. A voiced signal has fundamental frequency f_0, whose frequency domain expression is

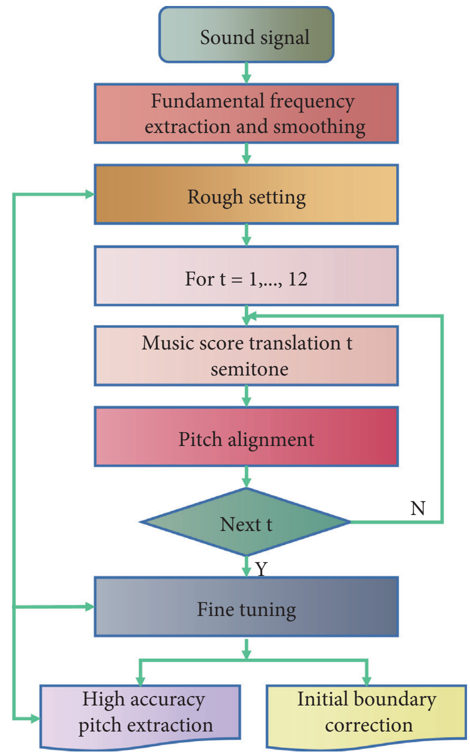

FIGURE 3: Automatic vocal music annotation model.

$$Y(f) = \sum_{k=1}^{K} a_k \delta(f - kf_0), \tag{7}$$

where a_k is the coefficient of the k harmonic.

Both singing and instrumental music have harmonic structure, so the mixed music spectrum has approximate sparsity. The comb filter can be used to extract the harmonic spectrum of the corresponding sound source according to the dominant fundamental frequency, and the MFCC (Mel frequency cepstral coefficients) of the extracted signal is sent to the neural network to judge whether the corresponding fundamental frequency is singing. Main melody discrimination steps:

A comb filter with a frequency range of 0–4 kHz is constructed from the dominant fundamental frequency F_0, as shown in

$$h(f) = \sum_{k=1}^{K} \delta(f - kF_0) * b(f), \tag{8}$$

where K is the number of harmonics in the range of 0–4 kHz; $b(f)$ is the basic waveform of comb filter (rectangle is used in this paper).

The MFCC is sent to the neural network to identify whether the dominant fundamental frequency F_0 is the fundamental frequency of singing.

Count the frame number of the fundamental frequency of the voice in each voiced segment, and if it is more than half of the total frame number of the voiced segment, determine that the dominant fundamental frequency track of the voiced segment is the main melody of the voice.

4. Results Analysis and Discussion

4.1. Evaluation and Analysis of Vocal Music. In this paper, the vocal music quality measurement method and scoring system are simulated on Matlab. The scoring test is mainly aimed at skill training etudes, which are the most commonly used etudes in vocal singing training. Focus on specific vowels, phonetic syllables, and skilled vocalization for targeted training. In the experimental simulation, five basic vowel vocal training materials *A*, *E*, *I*, *O*, and *U* and male closed humming training songs are selected for testing and analysis.

In the comparison of sound intensity, the average amplitude of each frame signal is calculated by the standard of practice music and the audition music, respectively, as the sound intensity parameter of this frame, thus drawing the volume intensity curve, as shown in Figure 4.

Although MT can bring many benefits to music teaching, teachers should grasp the utilization of MT and cannot let it replace teachers in teaching music knowledge. Teachers use MT in music classroom to improve classroom efficiency and teaching vitality. Therefore, in courseware making, they should not add too much content that is not related to classroom teaching, but should ensure that the whole courseware is simple and generous, which is convenient for teachers to operate and students to watch.

In pitch comparison, the fundamental frequency tracks of two pieces of music are obtained separately by cepstrum method, as shown in Figure 5. It can be found that the average standard fundamental frequency is 157.36 Hz and the average audition fundamental frequency is 159.01 Hz.

When calculating similarity, DTW (Dynamic Time Warping) method is used to get the average distance of the closest two features. Figure 6 is the DTW comparison between the standard song and the test song.

Here, it is important to point out that no matter how powerful and convenient MT is, it is only a teaching aid, which can only help teachers to impart knowledge and skills. Therefore, in the practice of vocal music teaching, attention should be paid to teacher-student interaction and the cultivation of the comprehensive quality of teachers and students. MT brings an opportunity for vocal music teaching innovation, which requires teachers to seize the opportunity, actively reform the teaching mode, enliven the classroom teaching atmosphere, break the limitations of traditional vocal music teaching, and let students have more room for development and innovation.

Teachers can use MT to simulate the stage background and stage performance situation for students, so that students can actively participate in stage performance activities, show their talents and skills, and increase their artistic expression. For example, in the practice teaching of vocal music performance for students, in order to bring students into the corresponding performance situation and motivate students to perform and show actively, teachers can use MT to simulate the stage background and stage performance situation for students, so that students can actively participate in stage performance activities, show their talents and skills, and increase their artistic expression. When students arrive, they will have a better understanding of vocal music knowledge and skills. They will also have close communication and interaction with other students, learn some useful methods and skills, and save money for their future growth and progress.

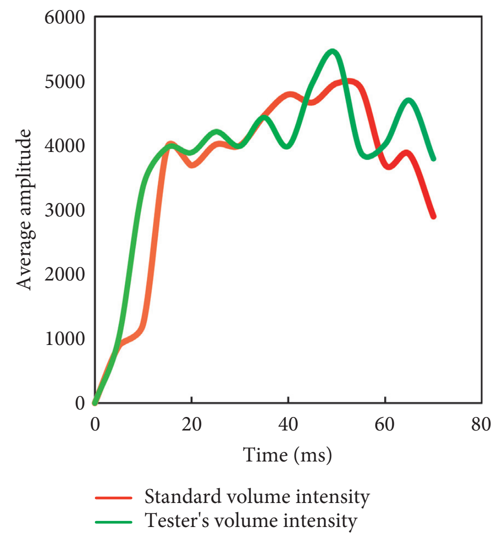

Figure 4: Men's voice closed hum practice music sound quantity intensity by line.

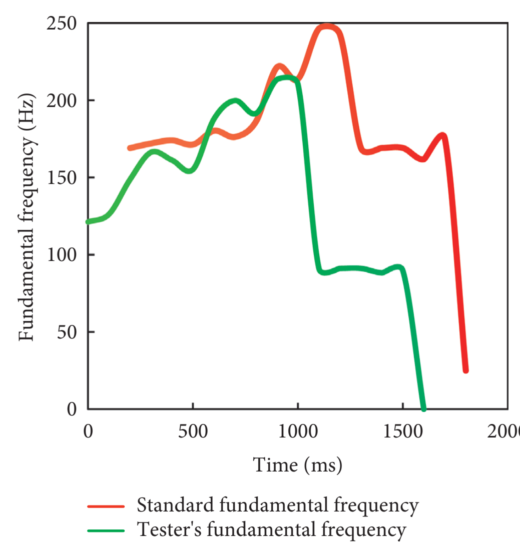

Figure 5: The track of the fundamental frequency of the male closed-mouth humming practice song.

4.2. Extraction and Analysis of Main Melody. Figure 7 shows the segmentation error rates of three models (initial model, model updated with all data, and model updated with reliable data) without smoothing the recognition results. For each model, the final segmentation error rates are compared when the presegmentation segment length changes from 0.1 to 1.0 s.

As can be seen from Figure 7, the data selection model updating algorithm based on confidence measure proposed in this study significantly reduces the error rate of music segmentation, and the segmentation result is further improved by smoothing the recognition result.

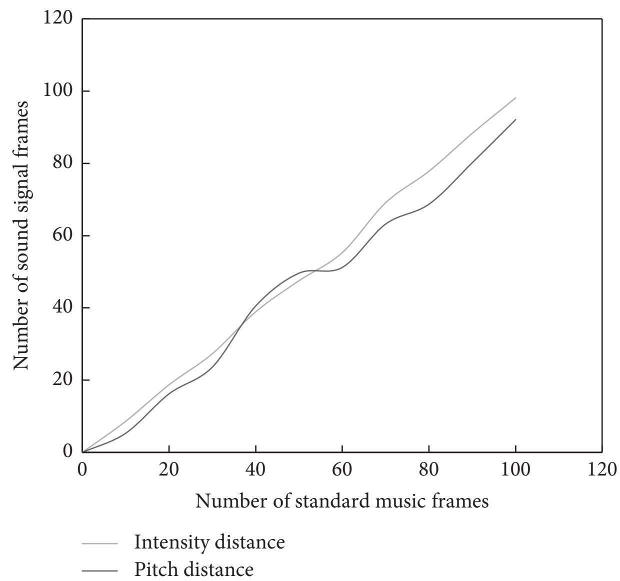

Figure 6: DTW comparison between standard song and test song.

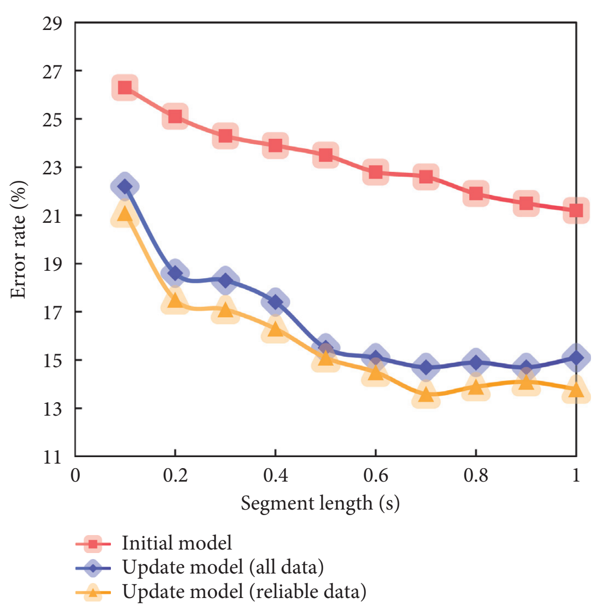

Figure 7: Unsmooched processing.

Figure 8 shows the corresponding segmentation error rate after smoothing the recognition result, where the error rate is defined as the percentage of the length of the incorrectly classified music signal to the total signal length.

Figure 8 shows that the smoothing process is effective when the length of presegmented segments is short. With the increase of segment length, the smoothing process causes each continuous segment to be too long but introduces additional segmentation errors.

Therefore, in music teaching, the subject should always be grasped, use MT appropriately and moderately, and do not become the teaching slave of MT. The use of modern educational technology means such as multimedia is just one of the ways of expressing teachers' creativity, a kind of teaching means and teaching methods, and a tool for serving teachers. To use it reasonably, it should not be used lightly; of course, it should not be used greatly, but it should be used by me. Teachers cannot rely entirely on MT to reflect their teaching level.

Figure 9 shows the minimum error rate value on each curve in Figures 7 and 8, that is, the best result obtained when the presegmentation length of each algorithm changes.

It can be seen from Figure 9 that the segmentation error rate is reduced from 18.6% to 13.9%. Compared with the

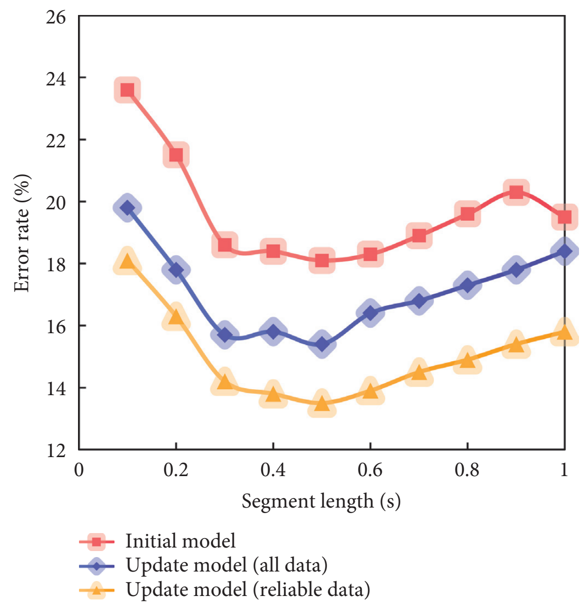

Figure 8: After smoothing.

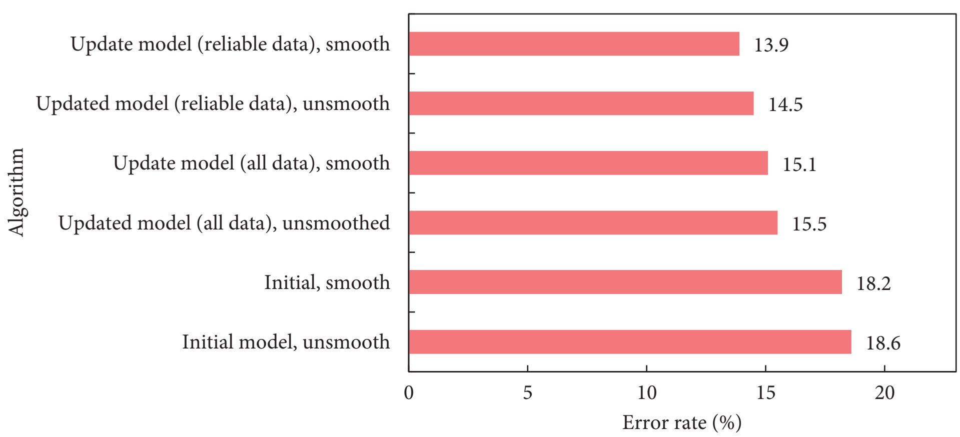

Figure 9: Comparison of music segmentation error rate.

original model and without smoothing, the segmentation algorithm proposed in this study has improved the error rate.

In order to verify the accuracy of the automatic extraction algorithm of vocal music melody, this section uses 500 pieces of music in the test set as test data and carries out the experiment under the condition that the signal-to-interference ratio is 5 dB, respectively. The experimental results are shown in Figure 10. Among them, the following five performance indexes are used to evaluate the algorithm performance [19]: VRR (Voicing Recall Rate), VFAR (Voicing False Alarm Rate), RPA (Raw Pitch Accuracy), RCA (Raw Chroma Accuracy), and OA (Overall Accuracy).

It can be seen that the overall accuracy of the main melody extracted by this algorithm reaches 86.24%. In this paper, the fundamental frequency discrimination model is introduced, and the statistical method is used to judge whether the dominant fundamental frequency track of each voiced segment belongs to the main melody of the song. Therefore, in rare cases, the song melody segment will be misjudged as the accompaniment melody segment, which will reduce the recall rate of melody location. However, in most cases, the accompaniment melody segment will not be judged as the song melody segment, which will reduce the false alarm rate of melody location and help to improve the overall accuracy rate of the algorithm.

To improve the comprehensiveness of students' knowledge in college vocal music teaching, in addition to thoroughly learning the teaching materials, it is necessary to increase classroom teaching capacity and expand teaching information with MT, so that students can fully grasp the connotation of works in future vocal music learning and

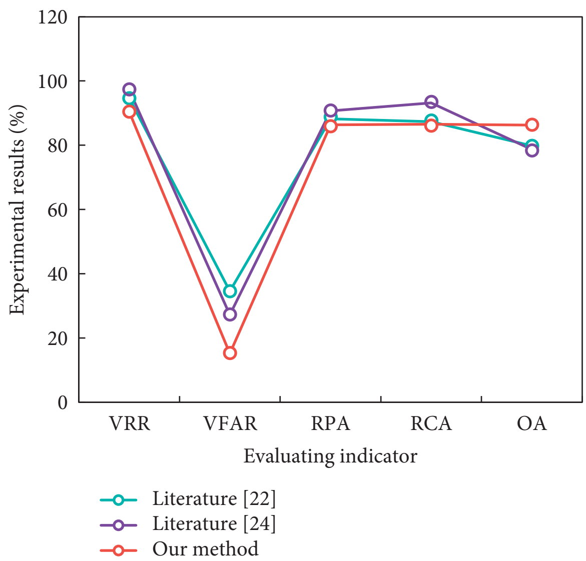

FIGURE 10: Experimental results when the signal-to-interference ratio is 5 dB.

practice. In the past, students could not form a systematic and deep impression from a single classroom explanation, nor could they access as much knowledge and information as possible. As a result, teachers can introduce MT, make full use of computers' powerful storage capabilities, actively consult a variety of materials and information, and provide rich information resources for vocal music instruction.

5. Conclusion

Combining college music teaching with MT meets the needs of the times. It can not only increase students' learning desire and improve students' learning ability, but also have considerable influence on teachers' teaching quality. It is the art of music, the art of practice, and the art of emotion. Simply emphasizing the description of language is boring for students. Teachers should understand students' aesthetic psychology of music when designing classes. By analyzing and displaying the waveform of the singer's voice, this paper makes vocal music teaching intuitive and visible. On this basis, according to the short-term stationary characteristics of the music signal, the instantaneous mutation error of the segment in the recognition result is further removed by smoothing the recognition result. Experiments show that the main melody extraction algorithm in this paper can effectively reduce octave error with a signal-to-interference ratio of 5 dB, the false alarm rate of melody location is obviously lower than other algorithms, and the overall accuracy is higher than other algorithms, which can effectively extract the main melody of vocal music.

However, there are still many shortcomings in MT teaching. Teachers need to improve the problems step by step according to their own actual teaching situation and improve the teaching quality to a new field by updating MT, so as to contribute to the cultivation of high-quality music talents in China.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analysis of Poetry Style Based on Text Classification Algorithm

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In order to realize the effect of intelligent poetry style analysis, this paper applies the text classification algorithm to the poetry style analysis, combines the knowledge representation algorithm to perform text classification and recognition, improves the algorithm, and applies it to the poetry style analysis model. Moreover, this paper combines intelligent algorithms to construct a poetry style analysis system, constructs the system's functional modules, preprocesses the poetry documents in the corpus, and maps them to the vector space that can be directly processed by the computer. In addition, after constructing the system model, this paper verifies the poetry style analysis system based on the text classification algorithm through simulation experiments. From the research results, the effect of the poetry style analysis method based on the text classification algorithm proposed in this paper is very good, which meets the actual needs of poetry style analysis.

1. Introduction

At present, a lot of progress has been made in natural language processing technology. As a branch of natural language processing, computer processing of literary language is now in front of academia. With the support of the National Natural Science Foundation of China, this paper is trying to make preliminary explorations in this field. The focus of this paper is how to use machines to realize the style of poetry. As one of the essences of Chinese traditional culture, the classical poems have meaningful meaning, simple and deep sentiment, and their style is intoxicating. However, for a long time, the judgment of the style of poetry works is mostly based on the reader's judgment and cognition of the style based on experience and feeling. Moreover, traditionally, there are no clear quantitative rules and no formal rules. For machines, it can only rely on the text content of the poem to determine the style. From the form, the poem is also a paragraph of text, and the judgment of its style can also be regarded as the classification of the text style. Therefore, this problem is essentially transformed into a text classification problem in machine learning. That is, under a given style classification system, the machine automatically learns the rules according to the content of the text, and establishes a classification discriminator according to the rules, and the classification discriminator automatically determines the style of the text. Based on this, this paper proposes a model framework for computing the style of Chinese classical poetry based on machine learning. This research is of great significance for expanding the application field of machine learning, for the informatization and excavation of traditional poetry, and for the language understanding of poetry and the computer-aided research of various literary works.

As one of the treasures in the history of Chinese literature, poetry has been passed down through the ages because of its enduring charm. This literary form, favored by the general public and literati and poojas, has been growing, evolving, and disseminating and has reached the peak of its development in the Tang and Song dynasties. The research on Tang poetry has always been a research hotspot among scholars and literary lovers. Since ancient times, countless experts and scholars have carried on extensive and in-depth research on Tang poetry and poetry from a literary perspective. However, with the continuous development of information science and technology, people have begun to try to use information science and technology to deal with some of the language problems encountered in work and life. Natural linguistics has developed rapidly in recent years. Faced with the victories of natural language processing in modern Chinese, some natural language processing methods are applied to ancient poetry. At the same time, in view of the difference between ancient poetry and modern Chinese, from the perspective of computer, integrated data mining, genetic algorithm, and other technologies and resources such as HowNet, it focuses on the application of text classification technology in the classification of poetry style.

In the process of creating poems, the different talents, temperaments, literary accomplishments, life experience, ideological realm, and ideological feelings of the literati and the ink guest will affect the content and expression of the poems written by the literati and ink guest, and they will also have the ability to Poems with different characteristics, therefore, do not have the same style of poems. However, in the process of appreciating classical poems, if you blindly pay attention to the individual differences between poems and ignore the common characteristics of the poems, it is likely to cause the problem of nihilism.

This article combines the intelligent computer algorithm to apply the text classification algorithm to the poetry style analysis and builds an intelligent classification system, which lays the foundation for the intelligent classification of poetry.

2. Related Work

Using computer technology to assist in the study of the field of classical poetry literature, some scholars have begun preliminary attempts and explorations early on. The construction of the classical poetry database and cultural knowledge base is in the computer research laboratories of some universities and research organizations [1]. With the increasing progress of natural language processing technology in the study of Chinese language, it can even gradually support the analysis of rhythm, emotional element, and style characteristics of classical poetry [2]. "Computational Poetics" is proposed in this context [3]. There have been many research results on the related fields of poetry style. According to the literature [4] "The topic model-based corpus construction and computer-aided creation research," the topic model based on LDA uses the method of reference word recommendation to study and analyze the word characteristics in poetry, vocabulary semantic analysis, and style feature analysis. Literature [5] uses the vector space model (VSM) to represent the text of poems and proposes two types of classification models of classical poems, bold and graceful and graceful. The classification models are based on machine learning and natural language processing. Poetry styles are classified, and a good judgment effect has been achieved. According to literature [6] after segmenting the poems according to the poetry metric and statistical word segmentation methods, they established a poetry vocabulary database and used machine learning methods to analyze the characteristics of poetry styles, classification evaluation, and sentiment analysis. In addition, research in related fields has focused on the algorithm improvement of the poetry style machine classification model, in order to gradually improve the accuracy of the classification model for the poetry style evaluation. The early stage corpus construction and computer processing procedures have been very clear. Various research work is still in-depth [7]. It can be seen that there have been quite a lot of research studies on the classification and judgment of poetry style, which has accumulated rich experience for the classification and judgment of poetry style based on machine learning in this article.

The handling of poems can actually be regarded as a text handling problem with a special content in form [8]. Literature [9] developed a "Poetry Computer Aided Research System," which takes the vocabulary in the poem as the main research unit to realize word retrieval, word frequency statistics, and image indexing. Literature [10] proposed a natural language processing technology based on word connection and used it for the understanding of poetry language. It successfully carried out a test of poetry vocabulary material labeling, a preliminary analysis test of poetry language, and an evaluation test of poem language boldness and graceful style. Literature [11] combined naive Bayes with the genetic algorithm, and put forward a calculation model for judging the bold and graceful style of classical poetry based on each character of the poem as the smallest unit, and tested the corpus in the classic poetry. Good results have been achieved. Literature [12] introduced Bayesian classification technology into poetry research from the subject point of view and achieved good experimental results. Literature [13] proposed a classification method of poem topics based on point mutual information and LDA and achieved a good classification effect on the relationship between poem topics and the evolution of the times. Literature [14] uses the vector space model (VSM) to convert the poetry text into a vector and selects the word feature through the chi-square test. Finally, the text classifier is constructed based on the naive Bayes and support vector machine algorithm, and the average classification accuracy rate reaches 74.7%. With the rise of deep learning, the literature [15] applied the RNN neural network to the generation of ancient Chinese poetry, and used the entire historical corpus of poetry as training corpus, adding certain constraints between the words and lines of the generated poetry to achieve it has a better effect than the traditional poetry generation system. Literature [16] uses the RNN model to generate poetry quatrains, and successfully adds an attention mechanism, so that the poetry can learn semantics, structure, rhyme, and other information at the same time. Literature [17] based on the RNN model, by optimizing the word vector of poetry, introducing attention mechanism and hybrid training, a model that can produce topic-related poems based on keywords has been obtained, and good results have been achieved.

3. Knowledge Representation of Intelligent Poetry Text Generation System

Like many other intelligent systems, knowledge representation is a very important key decision during system construction. We treat Chinese characters and works of art as images in a parametric form. Mathematically, the "image" of Calligraphy C is represented as a band-shaped image area covered by a series of ellipses. It means that this series of C is composed of num_0 ellipses $P_1, P_2, \ldots, P_{\text{num0}}$. $F0 = \{1, 2, \ldots, \text{num}_0\}$, (x_i, y_i), and a_i, b_i are used as the center, semimajor axis, and segment semiaxis of ellipse P_i, respectively. We define the text of traditional Chinese poetry as

$$\text{Area} \triangleq \left\{(x, y) \in R^2 | \exists i \in F_0, \frac{(x - x_i)^2}{a_i^2} + \frac{(y - y_i)^2}{b_i^2} \leqslant 1\right\}. \quad (1)$$

The above knowledge representation method is inspired by the method of the paper. In this paper, a band-shaped area is defined as an ellipse moving along a predefined curve.

We now turn to the concept of equivalence and use a formalized definition of the hierarchical representation of the text of poetry. If R is an equivalence relation defined in the $A = \{a_1, a_2, \ldots, a_n\}$ field, that is to say, R is as follows [18]:

(1) Reflexive,

(2) symmetrical, and

(3) passed.

Domain A can be decomposed into a series of subsets $A_1, A_2, \ldots, A_m$ in relation R, which satisfy the following properties:

(a) If $i \neq j, 1 \leq i, j \leq m$, then $A_i \cap A_j = \phi$ and

(b) $\forall a_i \in A, \exists j, 1 \leq j \leq m\$$, s.t. $\$a_i \in A_j$.

Under the equivalence relation R, if $(a_i, a_j) \in R, 1 \leq i, j \leq n$, we say that a_i is equivalent to a_j, which can be expressed as $a_i \underset{R}{\leftrightarrow} a_j$.

In order to establish the hierarchical representation of poetry text, we introduced four equivalence relations R_1, R_2, R_3, R_4:

R_1: all the structural ellipses used to form the same original sign are equivalent to each other.

R_2: all the original strokes used to form the same combination sign are equivalent to each other.

R_3: all the combined strokes used to form the same radical are equivalent to each other.

R_4: all the radicals used to form the same Chinese character are equivalent to each other.

We assume that the constructed ellipse $C = \{Pt | t \in F0\}$ is decomposed into num_1 equivalence classes under the equivalence relation R_1, which can be expressed as $F_1 \triangleq \{1, 2, \ldots, \text{num}_1\}$. The num_1 original signs are decomposed into num_2 equivalence classes under the equivalence relation R_2, which can be expressed as $F_2 \triangleq \{1, 2, \ldots, \text{num}_2\}$. num_2 combined strokes are decomposed into num_3 equivalence classes under equivalence relation R_3, which can be expressed as $F_3 \underline{\Delta_1} \{1, 2, \ldots, \text{num}_3\}$. The num_3 radicals are decomposed into num_4 equivalence classes under the equivalence relation R_4, which can be expressed as $F_4 \triangleq \{1, 2, \ldots, \text{num}_4\}$ [19].

In other words, in a specific poetic text work C, there are a total of num_1 original strokes $P_{1,i}\$, \$i \in F_1$. Moreover, C contains num_2 combined strokes $P_{2,i}, i \in F_2$. We can say that C has num_3 radicals $P_{3,i}, i \in F_3$. We can also say that C consists of num_4 words $P_{4,i}, i \in F_4$. Obviously, when we use the granularity of a single word to apply comprehensive reasoning, $\text{num} \equiv 1$[20].

Now, the hierarchical representation of traditional poetry text works can be formally described as follows:

$$\left\{\begin{array}{c} \mathbf{P}_{k,1} = \left\{\mathbf{P}_{k-1,s} | \mathbf{P}_{k-1,s} \overset{R_k}{\leftrightarrow} \mathbf{P}_{k-1,1}, \quad s \in F_{k-1}\right\} \\ \mathbf{P}_{k,l} = \left\{\mathbf{P}_{k-1,s} | \mathbf{P}_{k-1,s} \overset{R_k}{\leftrightarrow} \mathbf{P}_{k-1,q} \text{ in which q} = \min\left(t | \mathbf{P}_{k-1,t} \notin \bigcup_{i=1}^{l-1} \mathbf{P}_{k,i} t \in \mathbf{F}_{k-1}\right) s \in \mathbf{F}_{k-1}\right\}, \quad l \in \frac{\mathbf{F}_k}{\{1\}} \quad k = 1, 2, 3, 4 \\ P_{0,l} = P_l, \quad l \in F_0 \end{array}\right\}, \quad (2)$$

where the number of elements in the set M is $|M|$. Therefore, the following hierarchical relationship expressed in poetry text works can be expressed as follows:

$$\left\{\begin{array}{ll} \sum_{s=1}^{|F_k|} \left|\mathbf{P}_{k,s}\right| = \left|\mathbf{F}_{k-1}\right| = \text{num}_{k-1}, & k = 1, 2, 3, 4, \\ \left|\mathbf{P}_{0,s}\right| = 1, & s = 1, \ldots, \left|\mathbf{F}_0\right|. \end{array}\right. \quad (3)$$

This hierarchical representation describes how the poetry text works at the lowest level are composed of structural ellipses. Each higher level describes how to generate a representation of its current level from the information of the lower level. In essence, it is a tree-shaped knowledge representation.

At the 0th level of the hierarchical representation, the poetry text works are regarded as a series of ellipses, denoted as P_0. These ellipses are called structural ellipses for poetry text works. For each construction ellipse, it is denoted as $P_{0,i}$, and (x_i, y_i) is taken as its center, and ai and bi are taken as its semimajor axis and semiminor axis, respectively. Then, the image of the poetic text work C will be presented as a series of image areas covered by an ellipse.

If a lower-level element cannot be merged with other elements at the same level, it will be promoted to an adjacent higher-level element. In the same way, it is also possible that a radical will be downgraded into a combined gesture, or even an original one. Through these upgrade and downgrade arrangements, we have obtained a unified 6-level hierarchical system, which will be used in the generation of poetry text.

We denote the first structural ellipse of the poem text work as $P_{k,s}$, and its corresponding topological structure is $T_{k,s}$. $k = 1, 2, 3, 4, s \in F_k$°$\mathrm{T}_{k,s}$ contains topology information, and through it, $P_{k-1,1+1}$, $P_{k-1,2+1}, \ldots, P_{k-1}, |Pk, s| + 1\,(l = \sum_{i=1}^{s-1} |P_{k,i}|)$ can be used to form $P_{k,s}$.

We denote the bounding box of the image area occupied by element $P_{k,s}$ as $C_k \cdot s = [\,CX_{k,s}\$s\$\ CY_{k,s}\ CH_{k,s}\ CW_{k,}$ $s]$, $k = 1, 2, 3, 4, s \in F_k$. Here, $CX_{k,s}, CY_{k,s}, CH_{k,s}, CW_{k,s}$ are the x, y coordinates of the lower left corner of the bounding box $C_{k,s}$ and its height and width, respectively. All coordinates are in the world coordinate system. Therefore, we have

$$T_{k,s} \triangleq \left(\mathrm{TCR}_{k,s}, \mathrm{TCS}_{k,s}\right) \triangleq \left(\begin{bmatrix} TR_{k,1+l} \\ TR_{k,2+l} \\ \vdots \\ TR_{k,|P_{k,s}|+l} \end{bmatrix}, \left(\begin{bmatrix} TS_{k,1+l} & TS_{k,2+l} & \cdots & TS_{k,|P_{k,s}|+l} \end{bmatrix} \right) \right). \tag{4}$$

Here, $l = \sum_{i=1}^{s-1} |P_{k,i}|$; $s \in F_k$; $k = 1, 2, 3, 4$. $\mathrm{TCR}_{k,s}$ and $\mathrm{TCS}_{k,s}$ is the scaling and transition matrix, respectively. The strict mathematical definition of matrix $TR_{k,z}, TS_{k,z}$ is as

$$\begin{cases} TR_{k,z} \triangleq \begin{bmatrix} RW_{k,z} & 0 \\ 0 & RH_{k,z} \end{bmatrix} \triangleq \begin{cases} \begin{bmatrix} \dfrac{CW_{k,s}}{CW_{k-1,z}} & 0 \\ 0 & \dfrac{CH_{k,s}}{CH_{k-1,z}} \end{bmatrix}, & (k = 2, 3, 4), \\ \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, & (k = 1), \\ z = 1 + l, & 2 + l, \ldots, |P_{k,s}| + l, \end{cases} \\ TS_{k,z} \triangleq \left[RX_{k,z} \quad RY_{k,z}\right]^T \triangleq \begin{cases} \left[\dfrac{CX_{k-1,z} - CX_{k,s}}{CW_{k,s}} \ \dfrac{CY_{k-1,z} - CY_{k,s}}{CH_{k,s}} \right]^T, & (k = 2, 3, 4), \\ \left[0 \ \ 0\right]^T, & (k = 1). \end{cases} \end{cases} \tag{5}$$

If $k \geq 1, P_{k,i}$ m must be a combination of one or more construction elements one level lower. We call the latter substructural elements. All the information needed to combine $P_{k,i}$ is stored in $T_{k,i}$, which is the topology constructor of $P_{k,i}$.

Through the topology constructor, we can build a one-to-one mapping of different levels of hierarchical representation. In other words, any hierarchical representation pixel $[\,x_{k,s}\ \ y_k, s\,]^T$ of the s-th structural element $P_{k,s}$ belonging to the k-th level can be uniquely mapped to the hierarchical representation pixel $[\,x_{l,t}\ \ y_{l,t}\,]^T$ of the c-th structural element $P_{1,t}$ of the first level. Among them, $l > k, 1, k = 0, 1, 2, 3, 4, \exists m_j \in F_{k+j}\,(j = 1, 2, \ldots,$ $1 - k - 1)\$$ s.t. $\$P_{k,s} \in P_{k+1,ml} \in \cdots \in P_{k+(1-k-1),ml-k-1} \in P_{1,t}$.

If we introduce the operator $\nabla^b_{m,n}$,

$$\nabla^b_{m,n} \begin{bmatrix} x \\ y \end{bmatrix}_{2\times 1} \triangleq TR_{m+1,n} \begin{bmatrix} x \\ y \end{bmatrix}_{2\times 1} + TS_{m+1,n}. \tag{6}$$

Then, there will be a relationship:

$$\left[\, x_{l,t} \quad y_{l,t} \,\right]^T = \nabla^b_{l-1,m_{l-k-1}}\left(\cdots\left(\nabla^b_{k+1,m_1}\left(\nabla^b_{k,s}\left[\, x_{k,s} \quad y_{k,s} \,\right]^T\right)\right)\right). \tag{7}$$

The s-th structural element of the k-th level of the hierarchical system is denoted as $P_{k\cdot r,s}$, and its parameter is denoted as $E_{k\cdot s}, k = 0, 1, \ldots, 4, s \in F_k$. We now introduce a new matrix operator ∇^c_n, which can be used to generate an $\mathrm{m} \times \sum_{l=1}^n d_l$ -dimensional matrix $M = (a_{i,j}) m \times \sum_{l=1}^n d_l$ and n $m \times d_1\, (l = 1, 2, \ldots, n)$-dimensional matrices $M_1 = (a_{l,i,j})_{m\times d1}\, (l = 1, 2, \ldots, n)$. If $\nabla^c_n (M_1, M_2, \ldots, M_n) = M$, then we have

$$a_{i,j} = \begin{cases} a_{z+1,i,j} - \sum_{t=1}^{z} d_t \text{ in which } \sum_{t=1}^{z} d_t < j \leqslant \sum_{t=1}^{z+1} d_t, & z = 1, 2, \ldots, n-1, \\ a_{1,i,j}, & j \leqslant d_1, \end{cases} \quad i = 1, 2, \ldots, m. \tag{8}$$

We further define a matrix operator ∇^d_n:

$$\nabla^d_n (A) \triangleq \nabla^c_n \underbrace{(A, A, \ldots, A)}_{n}. \tag{9}$$

Then, the hierarchy of poetry text works can be formally expressed as follows:

$$\left\{ E_{0,i} = \begin{bmatrix} x'_i, & y'_i, \\ E_{k,s}, & = \nabla_{\left|P^c_{k,s}\right|}\left(\nabla^e_{k-1,1+l} E_{k-1,1+l}, \nabla^e_{k-1,2+l} E_{k-1,2+l}, \ldots, \nabla_{k-1,\left|P_{k,a}\right|+l} E_{k-1,\left|P_{k,s}\right|+l}\right). \end{bmatrix} \right. \tag{10}$$

Among them,

$$l = \sum_{i=1}^{s-1} \left|\mathbf{P}_{k,i}\right|, \quad k = 1, 2, 3, 4, s \in F_k. \tag{11}$$

At this time, the operator is defined as follows:

$$\nabla^e_{n,m} E_{n,m} \triangleq \nabla^c_2\left(\left(\nabla^c_2\left(TR_{n,m}, 0_{2\times 2}\right)\right)^T, \left(\nabla^c_2\left(0_{2\times 2}, TR_{n,m}\right)\right)^T\right) E_{n,m} + \nabla^d_{\mathrm{col}\,(E_{n,m})}\left(\left(\left(\nabla^c_2\left(\left(T\mathbf{S}_{n,m}\right)^T, \left[\, 0 \quad 0 \,\right]\right)\right)^T\right). \tag{12}$$

Among them, $\mathrm{col}\,(E_{n,m})$ is the number of columns of matrix $E_{n,m}$, and $0_{2\times 2}$ is an 2×2-dimensional zero matrix.

In the above equation, each $E0, i$ represents an area covered by the constructed ellipse, and $((x - x'_i)^2/a'^2_i) + ((y - y'_i)^2/b'^2_i) \leq 1$. This ellipse is the normalized version of the original ellipse $((x - x_i)^2/a^2_i) + ((y - y_i)^2/b^2_i) \leq 1$ for its bounding box. That is, if $P_{0,i} \in P_1$ and $j, i \in F_0, j \in F_1$ is assumed, we have

$$\begin{bmatrix} x_i' \\ y_i' \\ a_i' \\ b_i' \end{bmatrix} = \begin{bmatrix} \dfrac{x_i - CX_{1,j}}{CW_{1,j}} \\ \\ \dfrac{y_i - CY_{1,j}}{CH_{1,j}} \\ \\ \dfrac{a_i}{CW_{1,j}} \\ \\ \dfrac{b_i}{CH_{1,j}} \end{bmatrix}. \tag{13}$$

For an element higher than the 0th level, such as $P_{k+1,1}$, for all $k > 0$, it is composed of $N_{k+1,1}$ adjacent lower-level elements: $P_{k,11}, P_{k,12}, \ldots, P_{k,1Nk+1,1}$. The corresponding shape matrix $E_{k+1,1}$ is deduced, which is obtained from the matrix $E_{k,11}, E_{k,12}, \ldots, E_{k,1Nk+1,1}$ by linking columns by column. Because the parameterized representation of constructing an ellipse is a 4×1-dimensional matrix, the above-mentioned recommended connection method will accurately generate a matrix with only 4 rows at a higher level. Each row of the generated matrix is called the parameterized representation domain of the element. The different domains of an element can be inferred independently.

The weight associated with the s-th field of the i-th source knowledge on the k-th level; that is, the weight of the i-th training example $(p_{k,l}^i)$ is denoted as $w_{l,s}^i$. $w_{l,s}^i$ $(s = 1, \ldots, 4)$ is the reasoning strength of $p_{k,l}^i$ in synthetic reasoning. Therefore, the set of similar reasoning strengths arranged in order constitutes the "view sequence" of the current comprehensive reasoning process. This is what we said that different sequences of showing training examples will lead to different results of poetry text.

For the comprehensive reasoning process generated by novel poetry text works, we assume that n comprehensive source knowledge $P_{k,11}, P_{k,12}, \ldots, P_{k,\mathrm{ln}}$ at the k-th level participates in this reasoning process. Moreover, each comprehensive source knowledge consists of m components, where $\forall i \neq j; i, j = 1, 2, \ldots, n \Rightarrow l_i, l_j \in F_k, l_i \neq l_j$. Therefore, we can use an $m \times 1$-dimensioned matrix to represent a single comprehensive reasoning source and use an $m \times \sum_{i=1}^{n} l_i$-dimensioned matrix to represent all active sources in the current comprehensive reasoning. If we apply synthetic reasoning at the single-character level, then $m \equiv 4$. The t-th attribute of source knowledge is denoted as P_{k,li,t°, which has an associated strength $W_{k,li,t}$ in the process of comprehensive reasoning, and they have the following relationship:

$$\sum_{i=1}^{n} \omega_{k,l_i,t} = 1\,(t = 1, 2, \ldots, m). \tag{14}$$

In the intelligent poetry text generation system, this reasoning intensity can be adjusted through a graphical user interface. The new knowledge generated in the synthetic reasoning process is denoted as $P_{k,r}$, and its matrix form parameterization is denoted as E_{k,r°. To apply the principle of comprehensive reasoning process, all source knowledge in reasoning must have equal dimensions. That is to say, if we apply synthetic reasoning on source knowledge P_k, s and $P_{k,t}$, their corresponding matrix form parameterized representations $(E_{k,s})_{m1 \times n1}$ and $(E_{k,t})_{m2 \times n2}$ must satisfy the relationship $n_1 = n_2$. This equal requirement is a soft constraint of the synthetic reasoning process. If it is violated, we can introduce a source knowledge equality operator ∇_t^e to relax this soft constraint. This is very similar to the mapping problem in similar reasoning. Next, we will introduce a few symbols and define ∇_t^e in a strict mathematical way.

We first denote en, $i \overset{\Delta}{=} [\, \sigma(i,1) \;\; \sigma(i,2) \;\; \cdots \;\; \sigma(i,n)\,]T$, where $\sigma_{(i,j)} = \begin{cases} 1, & i = j \\ 0, & i \neq j^\circ. \end{cases}$

We can also obtain a discrete curve composed of the centers of all the covering ellipses for each structural element in the intelligent poetry text generation system, which can be expressed as P_k. Its corresponding parameterization is expressed as E_k, ls°. Therefore, a dispersion curve acquisition method can be described as follows:

$$\begin{aligned} C_{k,l_s} &= \left(\nabla_2^c\left(\left(e_{4,1}^T \times E_{k,l_s}\right)^T, \left(\mathbf{e}_{4,2}^T \times E_{k,l_s}\right)^T\right)\right)^T \\ &= \begin{bmatrix} x_1 & x_2 & \cdots & x_{co} \\ y_1 & y_2 & \cdots & y_{co} \end{bmatrix}, \quad co = \mathrm{col}\left(E_{k,l_s}\right). \end{aligned} \tag{15}$$

Then, an overview of the key columns of a matrix can be introduced and defined. If a curve C_k has $v + 1$ key points and its coordinates are $C_k, 1se_{co,u0}, C_{k,1se_{co}}ul, \ldots, C_{k,ls}e_{co.uv}$, respectively, then the key column of $E_{k,ls}$ can be identified as $E_{k,1se_{co}.u0}, E_{k,1se_{co},u1}, \ldots, E_{k,1s}e_{co.uv^\circ}$. Aiming at the key point extraction of a given plane curve $C_{k,ls}$, we use the algorithm introduced in this paper. Moreover, more refined key point extraction algorithms are introduced in, but they may cause more serious computational overhead.

We assume that now we have identified $v + 1$ key columns, which are the $u_0, u_1, \ldots u_v$-th matrix column, through the parameterized representation $E_{k,ls}$ of a matrix form of a comprehensive reasoning source $P_{k,ls}$, where $1 = u_0 < u_1 < \cdots < u_v \$\$ = \mathrm{col}\,(E_{k,ls}), s = 1, 2, \ldots, n.$ Therefore, we can define the capacity equality operator of the comprehensive reasoning source ∇_t^e as follows:

$$\left(\nabla_t^e\left(E_{k,l_s}\right)\right)\mathbf{e}_{t,i} \triangleq E_{k,l_s} e_{\mathrm{col}\left(E_{k,l_s}\right),\theta}, \quad i = 1, 2, \ldots, t. \tag{16}$$

Among them,

$$\theta = \left[u_j + \frac{u_{j+1} - u_j}{[t \times (j+1)/v] - [t \times j/v]}\left(i - \left[\frac{t \times j}{v}\right]\right)\right];$$

$$\left[\frac{t \times j}{v}\right] < i \leqslant \left[\frac{t \times (j+1)}{v}\right]. \tag{17}$$

$j \in \{0, 1, \ldots, v - 1\}; s = 1, 2, \ldots, n.$ [] is an integer trimming operator. Specifically, if each column of matrix $E_{k\cdot ls}$ is considered to be a key column, we can use a simpler mapping to define the operator ∇_t^e:

$$\left(\nabla_t^e\left(E_{k,l_s}\right)\right)e_{t,i} \triangleq E_{k,l_s} e_{\mathrm{col}\left(E_{k,l_s}\right),\left[i\times\mathrm{col}\left(E_{k,l_s}\right)\right]/t}. \tag{18}$$

Among them, $i = 1, 2, \ldots, t$, and [] is an integer trim function. Based on the definition of ∇_t^e, we can further define a comprehensive inference source knowledge superposition operator ∇_t^f:

$$\nabla_n^f\left(M_1, M_2, \ldots, M_n\right) \triangleq \nabla_n^c\left(\nabla_h^e\left(M_1\right), \nabla_h^e\left(M_2\right), \ldots, \nabla_h^e\left(M_n\right)\right),\quad h = \max\{\mathrm{col}\left(M_i\right)|i = 1, 2, \ldots, n\}. \tag{19}$$

Through the operator ∇_t^f, we can obtain the matrix representation of the superimposed comprehensive reasoning source:

$$E_k \triangleq \nabla_n^f\left(E_{k,l_1}, E_{k,l_2}, \ldots, E_{k,l_n}\right). \tag{20}$$

With this operator, we can further calculate the feature matrix of all comprehensive inference source knowledge:

$$S_k \triangleq E_k - \nabla_n^c\left(\nabla_h^e E_{k,\mathrm{nor}}\right),\quad h = \max\left\{\mathrm{col}\left(E_{k,l_i}\right)|i = 1, 2, \ldots, n\right\}. \tag{21}$$

In the above equation, b, E_k, nor are the matrix representations of standard source knowledge at the k-th level.

According to the user input intensity $w_{k,li,t}$ for different comprehensive reasoning sources, we can calculate the comprehensive reasoning viewpoint matrix:

$$W_{k,t} \triangleq \left(\nabla_n^c\left(\omega_{k,l_1,t}\times I_{h\times h}, \omega_{k,l_2,t}\times I_{h\times h}, \ldots, \omega_{k,l_n,t}\times I_{h\times h}\right)\right)^T. \tag{22}$$

Among them, $h = \max\left\{\mathrm{col}\left(E_{k,li}\right)|i = 1, 2, \ldots, n\right\}$. I_{hxh} is a hxh dimensional unit matrix.

Now, we can generate a comprehensive reasoning feature result $S_{k,r}$ through the comprehensive reasoning process described by the following form:

$$S_{k,r} = \left(\nabla_m^c\left(\left(S_k\otimes W_{k,1}\right)^T e_{m,1}, \left(S_k\otimes W_{k,2}\right)^T e_{m,2}, \ldots, \left(S_k\otimes W_{k,m}\right)^T e_{m,m}\right)\right)^T. \tag{23}$$

In the above equation, $\otimes$ is a comprehensive reasoning simulation operator. If the synthetic reasoning process models human creative thinking as a linear process, then $E_k\otimes W_k = E_k\cdot W_k$, where $\cdot$ is an ordinary matrix multiplication operator. If the comprehensive reasoning process models human creative thinking as a z-order polygon, then $\otimes$ will be defined as follows:

$$A_{p\times q}\otimes B_{q\times r} = C_{p\times r}\Rightarrow c_{i,j} = \sqrt[z]{\sum_{k=1}^{q}\left(a_{i,k}b_{k,j}\right)^z},\quad i = 1, 2, \ldots, p;\ j = 1, 2, \ldots, r. \tag{24}$$

We can also model creative thinking as a geometric average process, as shown in the equation of (25):

$$c_{i,j} = \sqrt[q]{\prod_{k=1}^{q}\left(a_{i,k}b_{k,j}\right)},\quad i = 1, 2, \ldots, p;\ j = 1, 2, \ldots, r. \tag{25}$$

Generally speaking, we can use the comprehensive reasoning model to overload the comprehensive reasoning simulation operator $\otimes$ to achieve the purpose of simulating different types of creative thinking.

Finally, by adding the shape of $E_{k,\mathrm{nor}}$, which is the standard structural element related to the inference result $P_{k,\mathrm{nor}}$ in the process of comprehensive inference, we obtain the parameterized representation $E_{k,r}$: $E_{k,r} = S_{k,r}\otimes\nabla_h^e E_{k,\mathrm{nor}}$ of $P_{k,r}$, where $E_{k,\mathrm{nor}}$ is the matrix form of the parameterized representation of the shape of $P_{k,\mathrm{nor}}$.

The definition of operator $\oplus$ can be overloaded to realize different novel creative thinking activities in intelligent systems. Some simple synthetic reasoning simulation operators for topology constructors are as follows:

(1) The arithmetic mean is

$$T_{k,r} = \frac{1}{n}\sum_{i=1}^{n}\left(T_{k,l_i}\times\omega_{k,l_i}\right). \tag{26}$$

(2) The geometric mean is

$$T_{k,r} = \sqrt[n]{\prod_{i=1}^{n}\left(T_{k,l_i}\times\omega_{k,l_i}\right)}. \tag{27}$$

(3) The harmonic mean is

$$\frac{1}{T_{k,r}} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{1}{T_{k,l_i}\times\omega_{k,l_i}}\right). \tag{28}$$

The integrated reasoning process proposed in this paper is essentially either a value process or an extrapolation process. In other words, w^i is the interpolation weight or extrapolation weight of $P_{k,l}^i$, and the constraint $\sum_{i=1}^n w^i = 1$ needs to be satisfied here.

4. Analysis of Poetry Style Based on Text Classification Algorithm

In the research of this paper, the judgment of poetry style based on machine learning, that is, the flow chart of the pattern recognition of poetry text, is shown in Figure 1.

The development and design of the system are shown in Figure 2 according to the research and processing sequence.

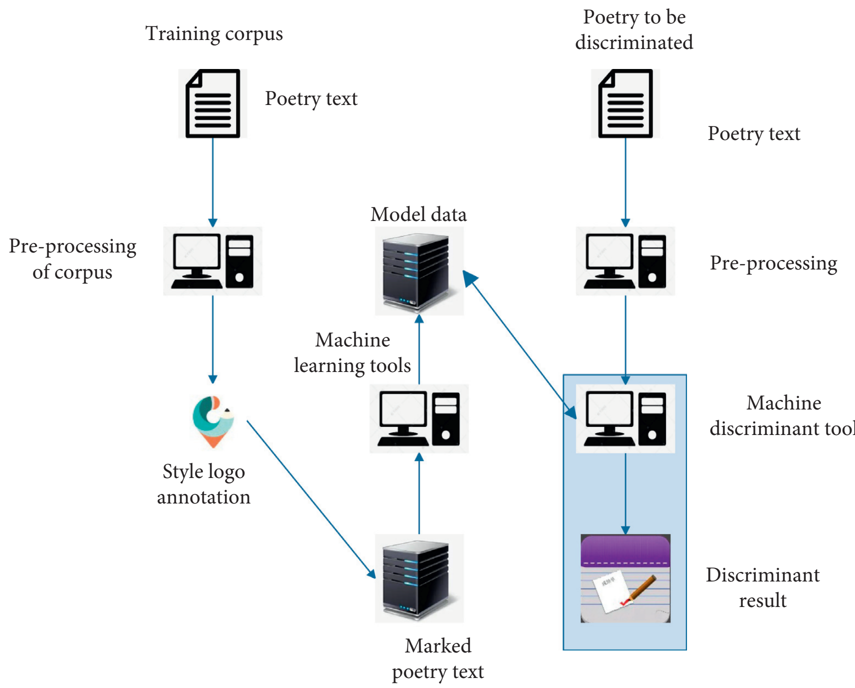

Figure 1: Flow chart of pattern recognition of poetry style.

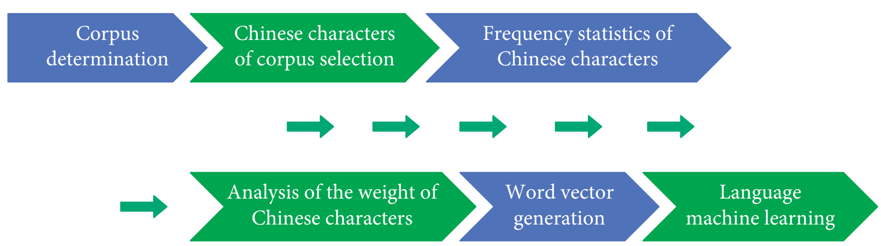

Figure 2: The processing flow chart of poem vocabulary material.

Judging the style of poetry is similar to the general process of text classification. First, the algorithm needs to preprocess the poetry documents in the corpus and then map them to the vector space that can be directly processed by the computer. The algorithm selects the poem documents that have been styled in advance as the training corpus and the test corpus. Subsequently, the algorithm uses machine learning methods to generate model data for style classification. Finally, the algorithm builds a machine judging tool for poetry style on the basis of the model data tested on the test corpus. This tool can judge the style of other poetry documents in the corpus. The flow chart of style evaluation is shown in Figure 3.

Poems are composed of text content and belong to unstructured data. It is difficult to analyze them using quantitative analysis methods. It is necessary to introduce data indicators that can be measured to perform data analysis and processing. The commonly used method is to segment the text content and then count the word frequency data. For high-frequency words such as "Wanli," "Jiangshan," "Dongfeng," and "Twilight" that often appear in poems, they can generally express the emotional bias and style characteristics of the poet's choice of poetry imagery. In order to classify and aggregate the genres of poets and poets, this paper mainly uses the method of high-frequency word statistics to classify and aggregate the style characteristics of the poets. The cluster analysis of word style is shown in Figure 4.

In order to obtain word vectors with more efficient algorithms, Word2Vec can efficiently train on millions of word lists and hundreds of millions of datasets. The obtained training result-word vector can well measure the semantic relevance and similarity between words. Word2Vec includes two network models: CBOW (Continuous Bag-of-Words) model and Skip-Gram model. The network structure is shown in Figure 5. Skip-Gram can be seen as the reverse process of CBOW. The essence of the CBOW model is a feed forward neural network language model (Feed Forward NNLM).

RNN is a neural network designed specifically for serialization problems, and its basic network structure is shown in Figure 6.

This article summarizes the sequence learning methods of the above two statistical language models. The framework

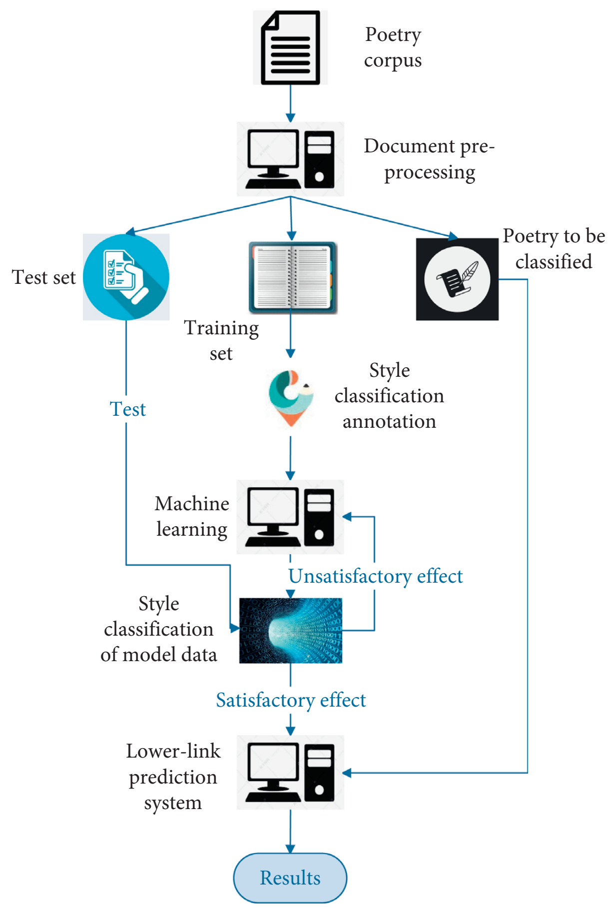

Figure 3: Poetry classification process.

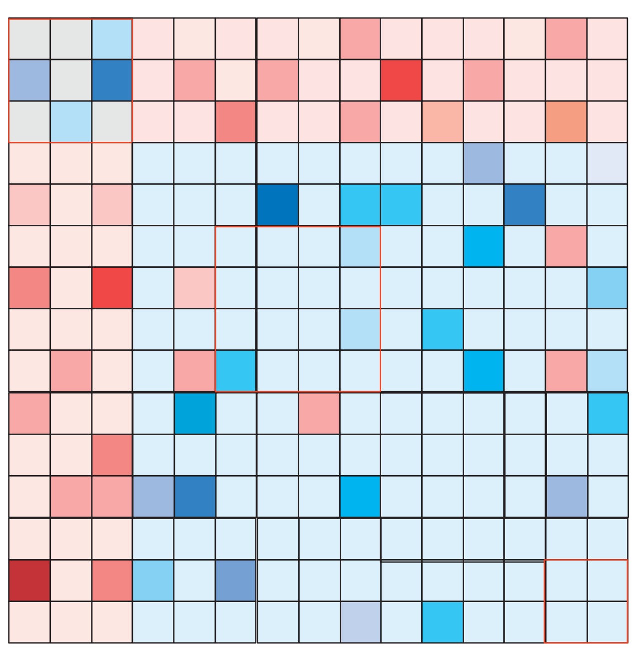

Figure 4: Cluster analysis of word style.

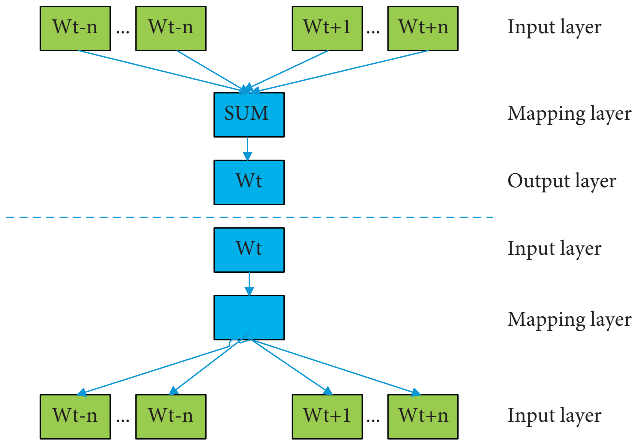

Figure 5: Structure diagram of CBOW and Skip-Gram model.

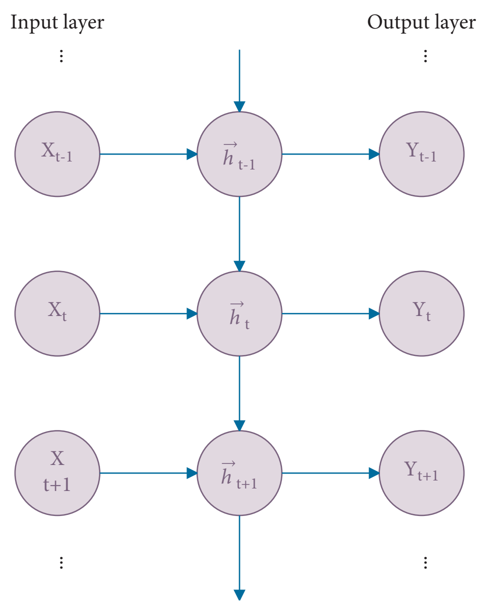

Figure 6: Basic network structure diagram.

of the joint language response model based on statistical learning is shown in Figure 7.

In the research of this paper, Brill's conversion learning method is used to cope with the generated context-sensitive rules in conjunction with the language. The flowchart of the learning algorithm is shown in Figure 8.

The text visualization technology is mainly composed of three modules: text analysis and processing, visual design presentation, and interactive design, as shown in Figure 9. First, the algorithm collects text information, preprocesses data and expresses knowledge, and transforms it into a corresponding structured data format. Then, the algorithm visually presents the information with graphics and color elements through visual coding. In the visual presentation, the algorithm should provide users with effective and reasonable visual presentation and interactive operations based on the user's cognitive characteristics. At the same time, the algorithm performs data operations on the visualized information elements through a reasonable interactive method to facilitate users to quickly and clearly understand the displayed information content, thereby realizing a complete visual design implementation process.

After constructing the above model, the effect of the model is verified, and the system function is verified based on actual needs. Moreover, this paper combines the simulation test to verify the effect of the poetry text classification and the poetry style verification of the system of this paper. The poetry text classification is shown in Table 1 and Figure 10.

From the above research, it can be seen that the poetry style analysis method based on the text classification algorithm proposed in this paper has a good classification effect. The experimental results of the poetry style analysis are shown in Table 2 and Figure 11.

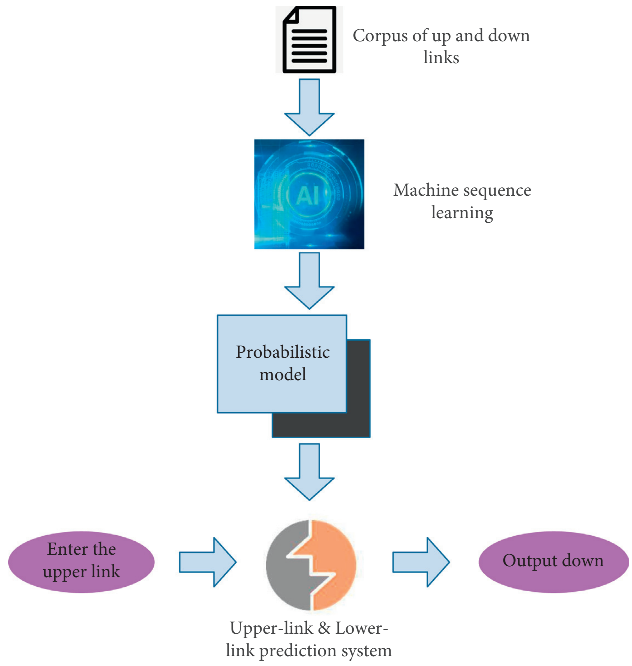

Figure 7: Schematic diagram of the joint language response model based on statistical learning.

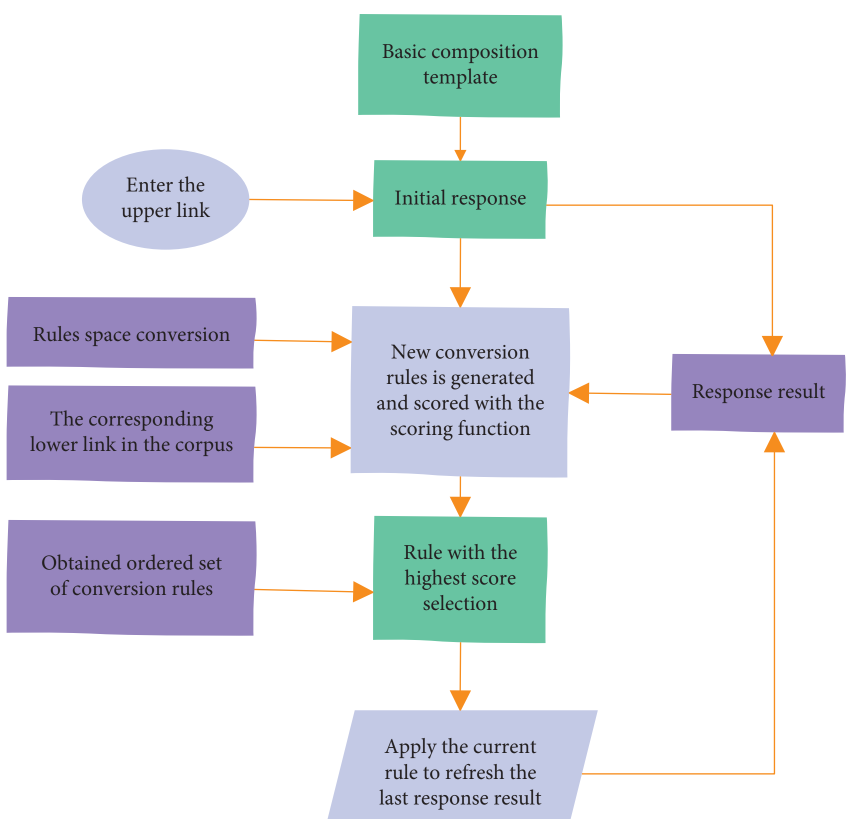

Figure 8: Schematic diagram of the learning of the joint language response model based on conversion.

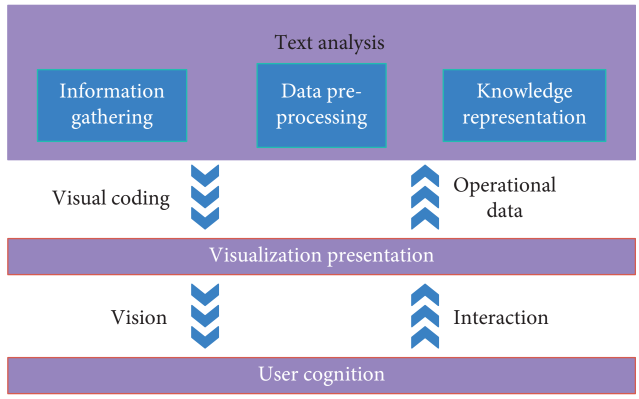

Figure 9: Logical architecture diagram of text visualization.

Table 1: Experimental data of poem text classification.

NO	Text categorization
1	94.63
2	94.29
3	94.85
4	95.85
5	94.73
6	97.07
7	97.45
8	97.61
9	95.50
10	95.52
11	95.88
12	93.56
13	95.88
14	93.99
15	93.27
16	96.85
17	97.69
18	96.65
19	96.70
20	94.01
21	95.60
22	94.70
23	93.27
24	94.92
25	95.53
26	93.17
27	96.02
28	93.14
29	97.77
30	97.40
31	96.08
32	94.40
33	95.91
34	95.88
35	94.45
36	96.50

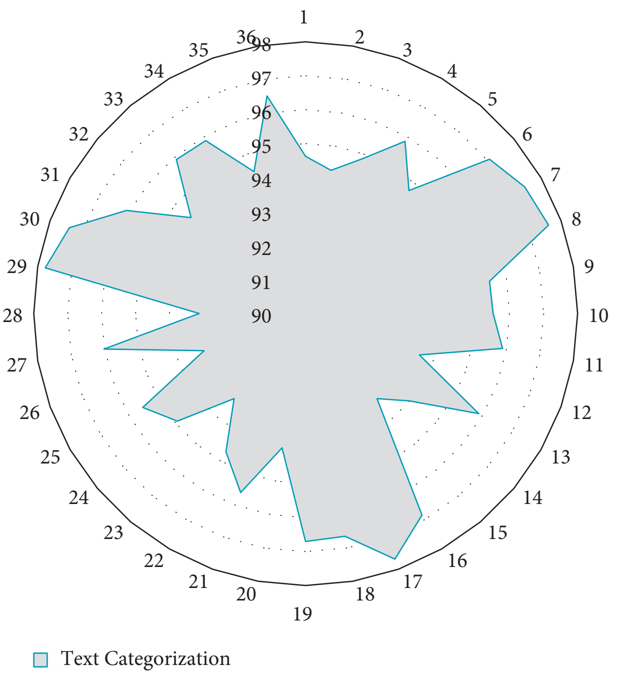

FIGURE 10: Statistical diagram of the evaluation of the classification effect of poetry text.

TABLE 2: Test data of poetry style analysis.

NO	Style analysis
1	75.40
2	76.61
3	76.06
4	88.70
5	82.39
6	84.98
7	91.28
8	83.30
9	81.22
10	78.60
11	83.99
12	81.16
13	79.14
14	84.99
15	84.50
16	79.33
17	73.70
18	74.90
19	89.73
20	87.79
21	76.67
22	89.30
23	91.01
24	76.10
25	89.19
26	80.65
27	90.65
28	74.65
29	91.06
30	90.54
31	84.27
32	84.07
33	77.95

TABLE 2: Continued.

NO	Style analysis
34	89.93
35	90.93
36	87.56

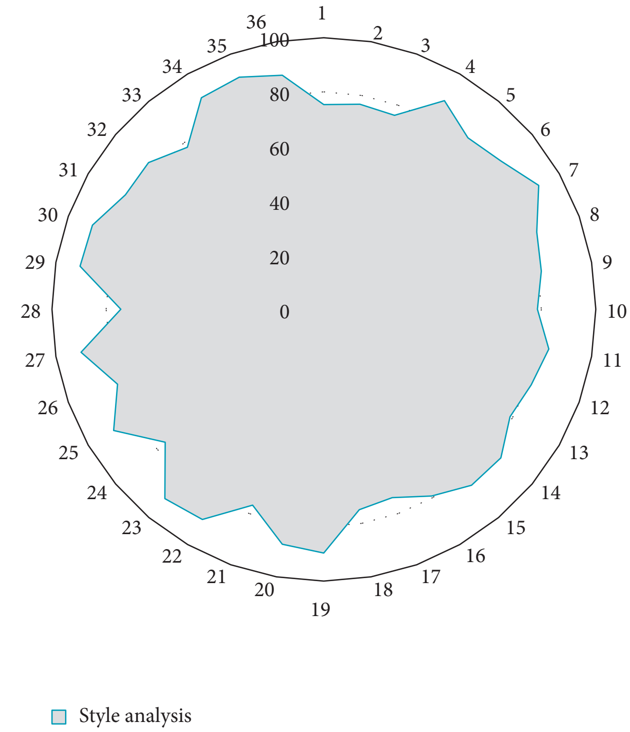

FIGURE 11: Statistical diagram of the effect of poetry style analysis.

From the above research, the effect of the poetry style analysis method based on the text classification algorithm proposed in this paper is very good, which meets the actual needs of poetry style analysis.

5. Conclusion

Before the classification of poetry text begins, the algorithm needs to represent the unstructured document data into a data form that the computer can understand. This requires the algorithm to perform corresponding preprocessing and feature representation of the document first and convert the unstructured or semistructured data form into a structured data form that can be processed by the computer. This includes a series of processes such as word segmentation, filtering of low-frequency words and forbidden words, feature representation, and feature extraction. The so-called word segmentation is to add a separator between each entry in a Chinese document to convert the continuous character stream form of the Chinese document into a discrete word stream form. At present, the main word segmentation methods used are forward and reverse maximum matching method, word-by-word traversal method, best matching method, and word frequency statistics method. In addition, there are two-scan method, adjacency constraint method, and so on. This paper applies the text classification algorithm to the analysis of the style of poetry and constructs an intelligent classification system. From the research results, it can be seen that the poetry style analysis method based on the text classification algorithm proposed in this paper is very effective and meets the actual needs of poetry style analysis.

Data Availability

The labeled dataset used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Predictive Skills and Reading Efficiency of College English Based on Multimedia Technology

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Slow reading speed is a common problem among Chinese college students' English learning, limiting the amount of reading done and thus directly affecting English-level improvement. Teachers in English classes place a premium on improving students' reading skills but the results are not immediately apparent. Even if many students have strong vocabulary and grammar skills, they will never be able to read English fluently. Teachers should prioritize not only students' knowledge acquisition and intelligence development but also the development of students' interpersonal skills and emotional intelligence in order to maximize their potential. This paper uses multimedia technology to investigate the role of multimedia technology in improving college English-reading efficiency and analyzes how teachers and students can play a positive role in improving the efficiency of college multimedia teaching using data mining technology, which shows that students' predictive reading skills can help them improve their reading efficiency. Teachers can also supervise and ask questions about students' learning progress via computers, communicate effectively with students, and provide timely feedback on students' learning results using multimedia technology.

1. Introduction

The rapid development of the economy and society is inextricably linked to the advancement of teaching activities and the innovation of teaching methods. Multimedia has permeated primary and secondary school classrooms in most areas as IT has matured, from tape recorders, slides, and physical projectors in the 1990s to today's network equipment, liquid crystal screens embedded on blackboards, and so on [1]. Teachers' teaching concepts and students' learning concepts both change as teaching media technology evolves [2]. As a result, we must improve the quality of teaching in the interaction between teachers, students, and the media. The positive role of teachers and students in transforming the benefits of multimedia teaching into the benefits of teaching quality is critical. Traditional teaching content and methods are insufficient to meet the demands of modern higher education, necessitating fundamental changes [3]. The traditional basic theory should be retained within the specified class hours, while new content should be increased, and the contradiction between more content and fewer class hours is becoming increasingly apparent [4]. Multimedia has become widely used in College English Teaching (CET) as a result of the advancement of computer technology and the popularization of scientific and technological applications, as well as the deepening of English teaching reform [5]. Realizing the informatization of teaching content, the strategization of teaching processes, the modernization of teaching means, and the networking of teaching resources to improve educational quality and promote the all-round development of students' mind and body quality has become the torrent of the general trend of English education [6].

Cultivating strong reading ability is always the primary task of CET. Its purpose is to enable students to use English as a tool to obtain the required professional information [7]. Educational informatization is the core feature of educational modernization, which means making full use of multimedia network to develop education in the information environment

[8]. With its outstanding advantages, multimedia teaching mode has been unanimously recognized by the majority of teachers and students. Nowadays, universities and even high schools begin to use multimedia technology to carry out teaching work. Although multimedia technology has been applied in teaching for many years, it has not reached the expected goal in terms of teaching efficiency and effect [8]. The core task of educational informatization is to build information-based educational resources. Under the guidance of scientific teaching mode, use information-based teaching means to cultivate excellent information-based talents needed by the society and develop educational informatization industry [9]. The problem of slow reading speed is common among Chinese college students' English learning. It restricts the amount of reading and directly affects the improvement of English level [10]. Based on multimedia technology, this paper studies the role of multimedia technology in improving college English-reading efficiency, analyzes how to give full play to the positive role of teachers and students to improve college multimedia teaching efficiency, and explains the role of students' prediction skills in reading in improving their reading efficiency.

In ordinary English teaching, teachers also attach importance to the improvement of students' reading ability, but the effect is not obvious. The result is that although many students have considerable vocabulary and grammar skills, they cannot become a fluent English reader [11]. For reading, efficiency is therefore important but speed is also another standard to measure reading ability [12]. Teachers recognize that a single language analysis and skill training cannot meet students' English needs, and they begin to prioritize the development of students' comprehensive ability to use English [13]. They also begin to prioritize the research of new teaching strategies, the change of traditional methodology, and the cultivation of students' comprehensive ability to use English. To ensure the normal operation of social order, informatization talents make full use of educational informatization resources to develop and improve informatization laws, regulations, and policies [14]. The educational cause is constantly developing, and the level of educational informatization is gradually improving in a virtuous educational cycle. Multimedia technology aids in the memorization and storage of educational material. It can store a large amount of teaching data, including various types of teaching content, test questions, statistical data, and so on, and it can be accessed by teachers and students at any time [15]. Multimedia technology can be used in the classroom to create an on-site teaching environment, make students feel immersed, not only increase students' interest but also help them understand and master knowledge, and improve teaching effectiveness [16].

The following is how the rest of the paper is structured: Sections 2 and 3 review the study's related work, Sections 3 and 4 describe the paper's methodology, Section 5 presents the experimental results and analysis, and Section 6 summarizes the findings.

2. Related Work

Teachers in traditional classrooms frequently attempt to accomplish this goal by carefully preparing the introduction or reading the text aloud. Students can be quickly immersed in the situation related to the artistic conception of the text using multimedia to play a piece of music or an image related to the artistic conception of the text. Silence can be turned into sound, complexity into simplicity, micro into macro, and abstraction into image with multimedia teaching, resulting in the best teaching environment and arousing students' strong learning interest. According to Bai [17], there are two basic criteria for evaluating classroom teaching optimization. One is the effect standard, which states that each student has attained the highest level of teaching, education, and development that he was capable of achieving during this time period. In a college English-listening class, Yao and Scheepers [18] use fragmented learning based on multimedia technology. Ma [19] conducted a feasibility study on multimedia-based college reading learning. By combining students' purposeful fragmented learning with teachers' classroom teaching, Proctor et al. [20] provide an empirical study on the integration of IT and English curriculum. Richards-Tutor et al. [21] used data mining (DM) technology to analyze the online learning process, laying the groundwork for mobile personalized learning research using DM technology. You et al. [22] develop an open-source adaptive hypermedia system through adaptive navigation support and adaptive presentation technology, establishes a user model based on the user's cognitive level and user's access status data, and users can set the rules of their own user model to realize adaptive recommendation of learning content and navigation. Gottardo et al. [23] propose to mark learning content, learner model, and learning strategy with metadata marking method, so as to formulate adaptive learning rule engine. Reading teaching is that students learn one text after another on the basis of literacy, and its ultimate goal is to make students become independent readers and masters of learning [24]. The research on teaching strategies and teaching effects of multimedia-assisted resources is abundant, and the effect of multimedia-assisted teaching is fully affirmed. However, there are still a few teachers who cannot give full play to the auxiliary role of multimedia-assisted resources, and more efforts should be made in the training of teachers using multimedia-assisted teaching resources and the autonomous learning of students using auxiliary resources. Based on DM technology, this paper dynamically tracks the learning behavior and records the learning track in real time and then analyzes the positive significance of multimedia for improving college English reading efficiency.

3. Characteristics of Multimedia Teaching

Multimedia teaching that incorporates computer and network technology can not only complement traditional teaching but also provide benefits that traditional teaching cannot. The ability to optimize classroom teaching is becoming increasingly apparent thanks to modern multimedia technology. The development of people, particularly the development of personality, is at the heart of optimization theory. Text, pictures, sounds, images, and other different media information are all combined in multimedia teaching, making it more concrete and vivid than traditional blackboard or single media teaching [25]. The task of comprehensively solving the tasks of students' academic achievement, language practical application ability, and intelligent development is at the heart of CET optimization. Dealing with the relationship between time, energy consumption, and educational effect is the key to success. Multimedia technology's main purpose is to present various types of information to students, such as words, images, and sounds, using computer technology and automation technology, which is a new modern teaching method. Traditional teaching methods cannot be realized solely from this perspective. The reform of traditional teaching methods will greatly improve current education and teaching efficiency precisely because of the obvious advantages of multimedia teaching in these aspects.

You can prepare and make courseware in advance as a teacher during lesson preparation. As a student, I sometimes have trouble hearing the teacher's questions clearly, and my notes are incomplete or absent-minded. The use of multimedia technology can also help to improve the effectiveness of instruction. Multimedia instruction is a type of audio-visual instruction. It can attract students' attention and improve students' interest in learning through an effective combination of pictures and sounds, resulting in the best teaching effect [26]. As a result, multimedia technology is closely linked to improving classroom teaching. Multimedia teaching makes use of a computer network's connection point, allowing teachers and students to communicate with each other outside of the classroom at any time and from any location. In comparison to traditional single-mode teaching, multimedia teaching fundamentally alters traditional methodology by making the teaching process multidimensional, integrated, and interactive, which aids students in understanding and remembering the content and improves the teaching effect.

4. Application of Multimedia Technology in Reading Teaching

4.1. Enrich Reading Teaching Resources. Multimedia expands the breadth of reading teaching resources. The understanding of the article cannot be interpreted only from the text itself. Only through the introduction of the author's life and writing background, the comparison of related articles and the comments of others can we grasp the text from a higher angle. A courseware is like a movie, and it is often easier to design an excellent script because of the accumulation of teaching plans for many years. However, how to embody the intention and teaching ideas of scripts in courseware is not so easy, which is why the courseware written by a professional software designer according to the teacher's teaching plan often fails to achieve satisfactory results [27]. One-way communication of too many perceptual materials can strengthen stimulation, but it is also easy to cause sensory fatigue, which in turn leads to inhibition. Students are the main body of classroom teaching. In teaching activities, students' active thinking activities are the guarantee that the cognitive process can be effectively completed. Teachers should make effective use of the technical features of multimedia, such as expressiveness, controllability, and participation to guide students to participate actively.

In traditional teaching, English teachers only have limited resources for teaching reference and accumulated knowledge by themselves, and students can involve fewer resources. The process of resource sharing is often one-way. Multimedia teaching has completely broken this limitation. Teachers and students are faced with a great deal of relevant knowledge. Students have the ability to collect the resources related to texts in advance and do more extensive reading after class. The core elements and relationships of the model of co-creation and communication of multimedia educational resources are shown in Figure 1.

Multimedia teaching is the future development trend in education and teaching methods, and the quality of instruction will inevitably improve, with students being the primary beneficiaries. Students' primary role becomes more important as external objective learning conditions become more prevalent. Teachers must guide students to closely follow the text and read, as well as use multimedia to expand reading, to prevent students from becoming lost in the vast amount of information available on the Internet. The preview content assigned by the teacher should be closely related to the text as an aid to classroom teaching, such as clearly pointing out where the text's background, author's life, and other people's comments on this article can be found. Students' learning concepts should change in tandem with the advancement of modern educational technology, from text reading to hypertext reading, from hand-drawn to hypertext structure conception and writing. The multimedia teaching process essentially aligns with people's cognitive processes from perceptual to rational, allowing students' perceptual processes to be accelerated and cognition and understanding to be deepened. However, some students may struggle to adjust to the significant increase in classroom teaching information. Then, students should work on honing their ability to process a large amount of data. We discovered that in the past, film projection was used to deliver all of the teaching content at once. Although the amount of information was increased, different students' attention was easily dispersed on different information, resulting in an out-of-control small-scale teaching. Students can easily concentrate their attention by taking notes and thinking along with teachers' teaching ideas in traditional blackboard writing teaching, but the amount of information taught is relatively small. The research and practical application of multimedia teaching theory should be prioritized in schools. We should fully comprehend the multimedia teaching mode and make a greater breakthrough through continuous research against the backdrop of modern education and teaching theory.

Sustainability is the standard for judging the quality of teaching, transformation system, and subsystem. Based on the development speed of each subsystem:

$$D_i = a + \sum_{j=1}^{n} b_j p_j + r_i Y + u. \tag{1}$$

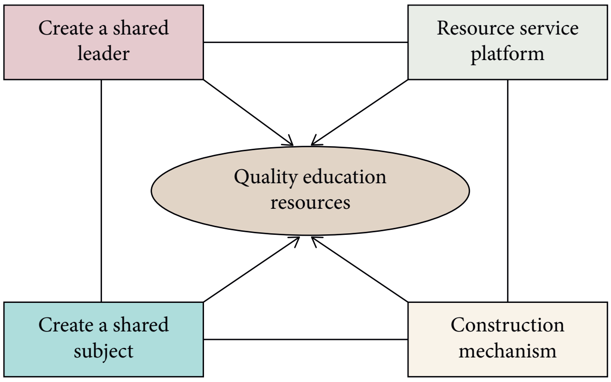

Figure 1: Educational resource sharing model.

Use clustering algorithm function method to find

$$D_i = a + \sum_{j=1}^{n} b_j \ln\left(p_j\right) + r_i \ln(Y) + u. \tag{2}$$

The calculated trend degree is

$$\ln\left(D_i\right) = a + \sum_{j=1}^{n} b_j \ln\left(p_j\right) + r_i \ln(Y) + u. \tag{3}$$

The traditional reading teaching resources are mainly words, supplemented by pictures, tapes, and other devices that can help students understand. In the process of multimedia teaching, these single media forms are compounded, and other forms such as animation, video, online courses, and online study groups are added on this basis, which innovates the means of reading teaching and makes the flat teaching method three-dimensional and comprehensive. Feedback can help teachers know the students' learning attitudes and emotions, the students' acceptance of multimedia teaching methods, the students' learning achievements, and other information in time. Feedback provides the basis for teachers to adjust and control various teaching designs including teaching degree, teaching progress, and teaching methods.

4.2. Improve Students' Reading Enthusiasm. Creating problem situations and implementing heuristic teaching is one of the most stimulating conditions for learning motivation. Students can assimilate new knowledge by applying their existing knowledge and experience in a real-world setting. Multimedia teaching is the future development trend in education and teaching methods, and teaching quality will inevitably improve, with students being the primary beneficiaries. The main role of students becomes more important as the external objective conditions of learning become more important. All human activities are dominated by needs, motives, and interests, according to psychology studies. Students' learning concepts should change in lockstep with the advancement of modern educational technology, from text reading to hypertext reading, from hand-drawn to hypertext structure conception and writing. The multimedia teaching process is designed to align with people's cognitive processes as they progress from perceptual to rational, allowing students to accelerate their perceptual processes and deepen their cognition and understanding. The implementation process of mixed English reading teaching based on multimedia technology is shown in Figure 2.

Students should approach the challenges posed by modern educational technology with optimism. On one hand, teachers should avoid situations in which students do not consider searching for answers directly on the Internet, such as writing extracurricular reading exercises by themselves based on the current situation of students in our school, or exercises after class that are primarily open-ended questions. On the other hand, to maintain communication and interaction, it is necessary to provide timely feedback to questions raised by students in the online learning platform. The main goal of multimedia teaching is to increase teaching efficiency and quality, so that students who are learning subjects can achieve high levels of learning efficiency only by giving it their all. According to modern teaching philosophy, class time should be reduced, and more time should be set aside for students to practice and think. An effective multimedia teaching process can effectively reduce classroom teaching hours, provide more time and space for students to learn independently, and increase the degree of freedom for students to design their own learning experiences. Students can independently search for a large number of reading materials and find out what they are interested in with multimedia, as long as the teacher chooses the theme. As the contents chosen by each student may differ significantly, students may experience double or even multiple reading effects as a result of their communication. Figure 3 shows a path analysis model for the construction dimension and learning effect of the English reading teaching environment.

Set up indicators for teaching quality evaluation. Describe them as the following quantitative comprehensive evaluation matter-element models:

$$\mathrm{CPV}(k) = \frac{\sum_{j=1}^{k} \lambda_j}{\sum_{j=1}^{m} \lambda_j}. \tag{4}$$

The matter-element model formed by the allowable value range of each index in the comprehensive evaluation of teaching reform is called the node-domain matter-element:

$$F_{ik} = \sum_{j=1}^{m} q_j x_{ij}. \tag{5}$$

Express the detected data or analysis results with matter elements:

$$f(t) = \sum_{j=1}^{N} \sum_{k \in Z} d_k^j \phi_{jk}(t) + \sum_{k \in Z} c_k^N \phi_{Nk}(t). \tag{6}$$

Use the weight coefficient of each feature to calculate the relevance of the teaching quality evaluation reform on the grade:

$$E_{mi} = \sum_{i=1}^{k} (i\Delta t) \cdot \left|S_{mi}\right|^2. \tag{7}$$

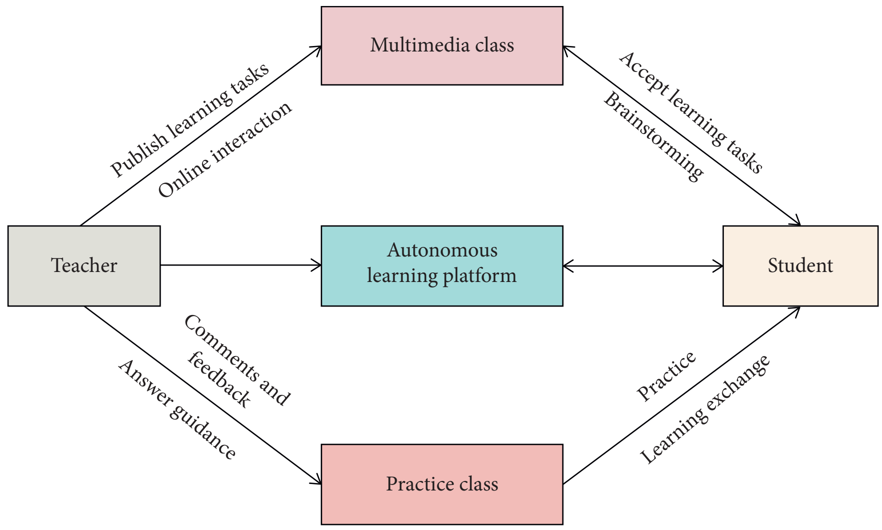

Figure 2: Blended English reading teaching.

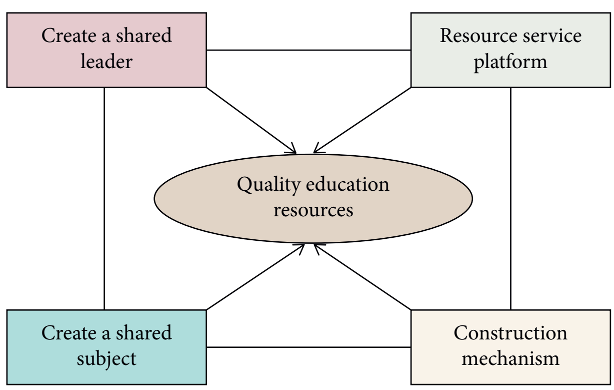

Figure 3: Path analysis model.

Students should actively cultivate their ability to acquire knowledge through various media in school so that they can continue to enrich and update their knowledge through various media once they leave school. Reading instruction can be made more orderly with the help of multimedia technology. Multimedia technology can assist teachers in providing reading instruction to students. Multimedia provides more possibilities for reading teaching as science and technology progress and teaching levels improve. Students can gain intuitive visual experience by transforming abstract images into concrete ones. Teachers can show students pictures of beautiful scenery during the course introduction to encourage students to love the motherland and nature when writing prose or poetry that depicts scenery. The primary goal of multimedia teaching is to increase teaching efficiency and quality, so that students who are learning subjects can achieve high levels of learning efficiency only by fully committing themselves.

5. Result Analysis and Discussion

Based on the teaching principle of constructivism, the teaching process is no longer a unilateral knowledge infusion, but the classroom is constructed by teachers and students. College English learning should create a real English-learning environment for learners with the support of multimedia network technology. In the real English-learning environment, learners re-organize and transform their own knowledge and experience and actively construct meaning to acquire new knowledge. The design of multimedia CET resources should conform to students' cognitive development level and psychological development law and design and select college English-teaching resources based on a full understanding of students' cognitive level and interests.

After the parameters are adjusted, the data flow quickly reaches a steady state. The initial rotation is too large, which may result in excessive data flow. Perform three sets of data testing and statistical results, as shown in Figure 4.

The main evaluation object and criterion for judging students' reading effect is the traditional teacher of reading teaching evaluation. It can be said that when the teacher is absent, the evaluation process becomes more difficult. However, when using multimedia reading instruction, the appropriate teaching software can be preprogrammed. After class, students can complete reading exercises based on the software's prompts, checking pronunciation, words, text comprehension, and other factors. The software can also make a corresponding evaluation on students' answers and enter different links, which not only saves teachers a lot of time revising exercises and explaining basic concepts but also allows students to receive evaluation feedback quickly after completing the questions. It is possible to generate and collect big data in the classroom, and it is critical for teachers to fully explore and practice these data. The simulation of multimedia education teaching design is analyzed from various angles during the teaching stage, using multimedia technology. The experimental results of three experiments are shown in Figure 5.

According to constructivist teaching theory, students' language skills must be acquired through a process of meaning construction, and learning a language in a real-world setting is the most effective method. Students benefit from the use of teachers' multimedia technology to create a

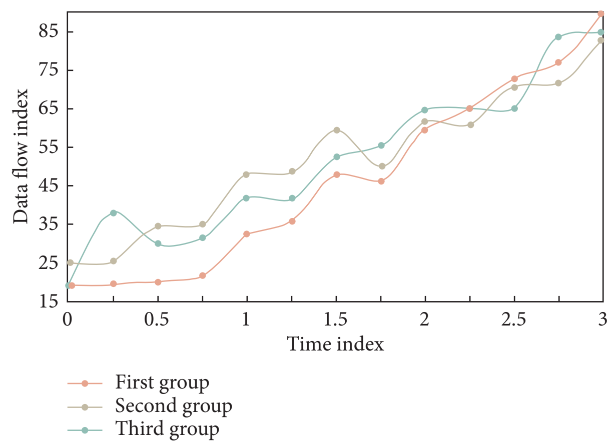

Figure 4: Data impact over time.

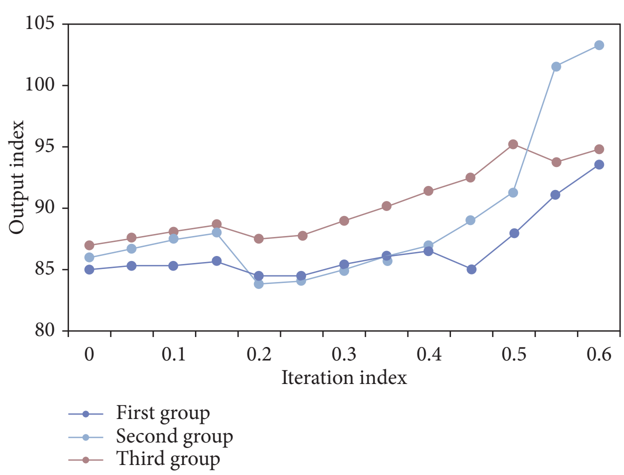

Figure 5: Iteration value and output relationship.

realistic learning environment. Students construct the meaning of knowledge and practice listening in this authentic language learning environment, which includes both visual and auditory stimuli. Multimedia teaching is an auxiliary teaching method in CET. Although multimedia technology can effectively improve the teaching effect in the classroom, teachers should still be in charge; multimedia technology can only serve as a technical auxiliary means for teachers to play the lead role. They can only assist teachers rather than replace them, and they cannot take over teaching responsibilities. A stage test should be conducted after the first stage of English reading instruction with multimedia is implemented. The test results serve as a foundation for not only evaluating students' learning effects at this stage but also for adjusting strategies at the next stage. The test results are shown in Figure 6.

According to the traditional way of reading evaluation, if teachers want to evaluate students' reading effect, they must do it in the classroom. However, using multimedia reading teaching and setting up an online learning platform, students can upload their collected reading materials and completed reading exercises to the platform, and teachers can give feedback immediately. For universal

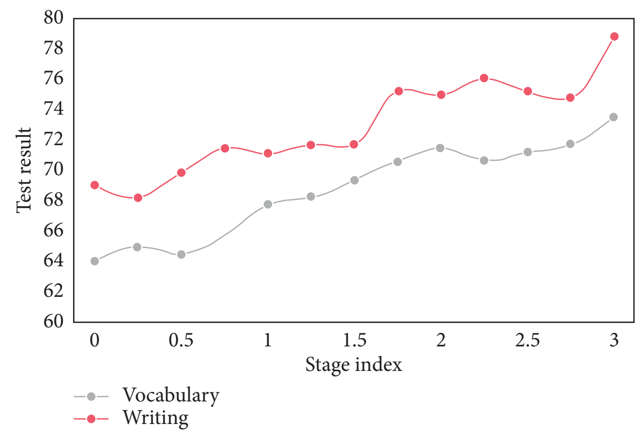

Figure 6: Comparison of achievements.

incomprehensible problems, teachers can also summarize them and re-emphasize them in class to deepen students' impression. Based on the developmental evaluation theory, multimedia-assisted CET resources must attach importance to the interest of the teaching process in the design process, so that students can experience the beauty of the teaching process, stimulate students' interest in learning and cultivate students' learning motivation. Teachers should inherit the essence of traditional methodology, seize the opportunity brought by modern IT revolution, give full play to the characteristics of traditional teaching methods and modern multimedia technology, complement each other, make full use of modern IT, such as multimedia and network, and promote the effective application of new teaching mode.

In CET, if the multimedia teaching system can be properly used to solve the audio-visual and other related teaching problems in English teaching, students can acquire basic English knowledge in a limited classroom, and at the same time, their basic language skills can be trained, thus achieving the real purpose of applying multimedia-assisted teaching system to CET. The results of the evaluation index parameters of reading teaching level can be regarded as the research object, and data clustering and information fusion are carried out. The evaluation results are shown in Figure 7.

The English proficiency test scores of the students in the experimental class and the control class were obtained, and the relevant data were statistically analyzed by statistical software. After the experiment, compare the class scores again. The results of the two classes before and after the experiment are compared as shown in Figure 8.

It shows that multimedia technology is of positive significance to improve college English prediction skills and reading efficiency. Using multimedia technology, teachers can also supervise and ask questions about students' learning progress through computers, communicate effectively with students and give timely feedback to students' learning results. Teachers can give students visual and auditory information through their own pronunciation, intonation, and expression, and then use the illustrated forms of multimedia to arouse their emotional resonance. With the support of multimedia technology, these advanced organizers are presented in the form of visual and dynamic images and videos, which changes the traditional

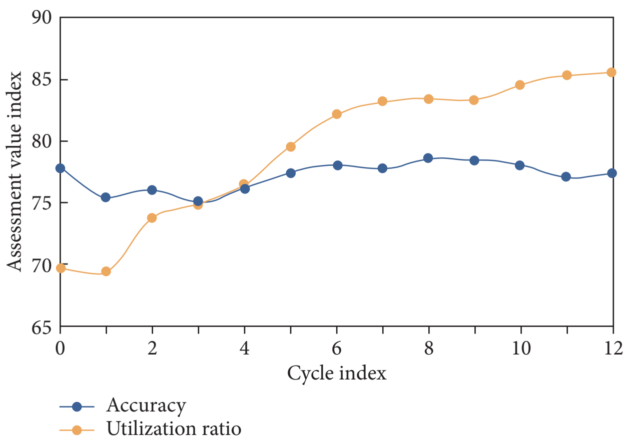

Figure 7: Evaluation test results.

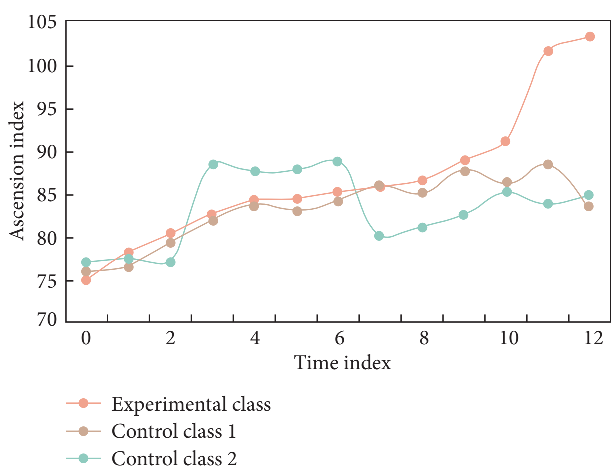

Figure 8: Comparison of results before and after the experiment.

presentation in the form of words and makes it easier for students to connect and integrate new and old knowledge, understand and master new knowledge in the process of learning new knowledge.

6. Conclusions

Education modernization is a widespread trend, but it must not become a form of zealous and blind pursuit. Instead, we should prioritize students' actual needs and implement multimedia instruction with the goal of improving students' reading efficiency. Improving the efficiency of reading instruction is not a simple task. The proper use of audio-visual media, on the contrary, has been demonstrated in practice to effectively stimulate students' learning subject consciousness, arouse their interest in learning, and achieve good teaching effect. Students construct the meaning of knowledge in this real-world learning environment using both visual and auditory stimuli, while teachers monitor students' learning progress and effect using multimedia-assisted teaching resources. The design of college English-assisted teaching resources should be based on the teaching principles of "student-centered, process-oriented, communication-oriented, and people-oriented," giving full play to the advantages of IT and multimedia resources in the educational information environment. We can only improve teaching efficiency and quality by organically combining multimedia technology, teachers' leading role, and students' main role. The breadth and depth of this study have some limitations, and some issues in the detailed explanation and discussion need to be investigated further in order to realize the optimization of college English classrooms in a multimedia technology environment.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

An Improved BP Deep Neural Network Multimedia Used in Oral English Training

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In order to improve the effect of spoken English training, this paper combines multimedia information technology to reform the teaching of spoken English training, and integrates BP neural network English into spoken English training. Moreover, this paper combines the actual needs of spoken English training and the teaching framework of the multimedia system to construct the data set, clean up the data set, and implement the word vector representation of students and professionals. In addition, this paper constructs the entire system framework of the spoken English resource recommendation algorithm based on the graph convolutional neural network, and combines the BP deep neural network algorithm to construct the spoken English training system. Finally, this paper designs an experiment to evaluate the effect of this system. The experimental research results show that the multimedia based on the BP deep neural network proposed in this paper has a good effect in the application research of spoken English training, and can effectively promote the effect of spoken English training of students.

1. Introduction

Oral expression ability, as an important English language skill, promotes the formation of students' English pragmatic competence, and is also an important manifestation of the function of English communication tools. Therefore, it has attracted great attention from teachers and students [1]. In particular, in the current college English classroom, teachers increase the intensity of the students' oral expression training, and hope to seize the golden period of language ability formation at the university stage to lay the foundation for the development of students' oral expression ability [2]. However, many teachers find that students lack enthusiasm for oral training in English classrooms, and their participation is generally low, which leads to unsatisfactory oral training effects, and the students' oral level is not improved. In view of this situation, teachers need to take a variety of measures to explore the reasons for the students' problems in spoken English training, design oral training strategies suitable for students, and improve students' spoken English level [3].

With the continuous development of the times, in order to cultivate more useful talents for the society, we also deeply realize that the teaching activities of teachers must closely follow the pace of the development of the times, so as to provide more effective guidance for students. English teaching can be divided into four teaching sections: listening, speaking, reading and writing. With the continuous development of the times, we have to admit that the ability of students to "speak" is becoming more and more important. However, as far as the current college spoken English teaching is concerned, there are still some problems that affect the further improvement of students' oral ability. Therefore, this paper makes a simple analysis on it.

For university students, there is also a factor that affects the improvement of students' oral English in the learning of oral English, that is, the students' oral foundation is relatively weak. Spoken language learning, especially for college students, does not start from scratch. Therefore, students will be affected by their existing oral language skills in the process of oral learning. Students generally do not dare to speak, inaccurate pronunciation and other phenomena. Students can use English for flexible communication requires a long-term practice process, and the first step is for students to have the courage to "speak" and boldly communicate in English. Only when students have the courage to speak, can they truly go out of spoken English learning. first step. However, college students generally do not dare to "speak". Students are afraid of inaccurate pronunciation and fear of saying wrong. This kind of fear of students has seriously affected the improvement of students' oral English ability. Oral English learning is different from the learning of other English knowledge sections. Only in a certain environment can students truly achieve the purpose of oral practice, and only in a certain environment can students' oral ability be truly improved. As far as the current oral learning of university students is concerned, there is no specific environment for students to practice a lot of oral English. Students' oral practice is only limited to classroom conversations or some English activities organized by the school. In fact, this is far from enough for students' oral practice.

For improving the current situation of college students' spoken English, it is crucial to pay great attention to spoken English. Teachers should pay attention to spoken English teaching, and students should pay attention to spoken English learning. First of all, teachers need to pay attention to spoken English teaching. This requires teachers to change the traditional English teaching concept and take the new teaching concept as the guide. Moreover, teachers should not only pay attention to teaching students in other parts of English, but also pay attention to oral teaching to students, and be able to introduce effective spoken English teaching methods into classroom teaching to improve the effectiveness of spoken English classroom teaching. In addition, teachers should make students understand the importance of spoken English teaching, and spend part of their English learning time on spoken English learning.

This paper combines the BP deep neural network algorithm to construct an spoken English training system to improve the intelligent effect of spoken English training, and evaluates the performance of the system through experimental research.

2. Related work

Literature [4] believes that programmed language is "a part of automatic or semi-automatic memory reserve, even through the screening mechanism of dividing these words, they are still automatically stored". Literature [5] believes that spoken language is a series of words that people habitually use together. Literature [6] proposed that spoken language is a way for the sharing of words in natural texts to reach a statistically significant number: from the perspective of language programming, Wray's term "programming language" has a far-reaching impact. Formula language refers to: it is a combination of continuous or discontinuous words or other elements, is orderly and prefabricated: it is stored and retrieved as a whole in the process of language use, and is not affected by the generation and analysis of grammar Influence. Literature [7] proves that word chunks are cognitively processed as a single vocabulary unit. Moreover, word blocks are learning materials suitable for human cognition.

Literature [8] pointed out that there are a large number of lexical sequences ylJ (sequences) in English, and a large number of prefabricated sentences of this kind exist, which explains to us why the language of second language learners can be "as fluent as native speakers." And the answer to "choose like native speakers". Literature [9] pointed out that many of the native language users' knowledge are spoken languages that are not required and impossible to analyze outside of grammar. He explained that communicative competence is actually the ability to master a large number of assembled structures, formulaic formulas and a set of rules, and be able to make necessary adjustments according to the context. Literature [10] believes that language is not composed of traditional grammar and vocabulary, but composed of multi-word prefabricated spoken language. Literature [11] pointed out that the degree of language fluency is determined by the amount of programmed language stored in the brain's memory, rather than by the knowledge of grammar. Literature [12] pointed out: learning spoken language is more important than learning grammar, language knowledge is spoken knowledge to a considerable extent, and grammar is second. Literature [13] believes that spoken language is the basis of second language learning, and the teaching of common phrases (stock phraSe) in language teaching should be as important as vocabulary and grammar teaching.

Literature [14] studied the differences between college students and middle school students in the use of spoken English, and pointed out the wrong ways of using spoken English by students. Chinese English learners seldom use multiple words and idioms in oral English, and there are differences in the frequency of use of phrase structure and sentence structure. There is a significant difference between the oral language use of domestic speakers and English speakers. There is no significant difference between college students and middle school students, while the oral language use of college students is significantly higher than that of middle school students. Spoken language errors in oral communication include mother tongue transfer errors, acquisition errors, and redundancy Errors, mixed use errors, etc.

Literature [15] believes that: in the aspect of language learning, oral input can reasonably configure the cognitive resources of information processing; in the aspect of oral language, prefabricated oral language can help to communicate meaning first and coherently; in the aspect of reading, oral language is effective Prefabrication can process low-end information more quickly, thereby speeding up reading; in terms of writing, spoken language has a good effect on preserving short-term memory, and can vividly express one's thoughts in words. Literature [16] believes that the richer the storage of spoken language, the more proficient in calling the spoken language, which has a positive impact on all aspects of language learning, listening, speaking, reading and writing. Literature [17] pointed out: oral language also has its own limitations. In language learning, oral input cannot be one-sidedly emphasized, while grammar and other indispensable aspects of language learning are ignored. It is necessary to ensure that learners can stay in language learning for a long time. In order to make progress, only by correctly handling the direct relationship between oral input and grammar, and making up for each other's shortcomings, can the various abilities of the language develop in a co-ordinated manner. Literature [18] did research on whether the use of spoken language affects spoken English and writing. It is believed that the use of spoken language can affect students' English spoken and written scores, and the impact is greater. Compared with grammar knowledge, spoken language is in the structure of English knowledge. Obviously occupies a more important position. The oral English level of students largely depends on their ability to call the oral English in their minds. Students who can call as many oral English as possible more accurately tend to have higher oral English. The literature [19] found that the higher the student's writing score, the more proficient and richer the oral English.

3. Construction of spoken English resource recommendation model based on BP deep neural network

This article analogizes students as users, majors as projects, and students' class relationships as users' social networks, and establishes a professional recommendation model based on students' social interactions. The characteristics of students in social networks will be spread, which affects students' professional choices. Therefore, the influence propagation layer is introduced into the social recommendation network, and then a better loss function is selected to improve the accuracy of the recommendation result. The spoken language resource recommendation model proposed in this paper is divided into three parts. The first part is student modeling, which is divided into two models. The first model is to understand students' preference for majors through the interaction of the student-professional diagram. The second model extracts student characteristics from social networks, and integrates the characteristics of student friends into each student node in the social graph to model students. Combining the information of student-professional space and social space, the potential characteristics of students are intuitively acquired. The second part is professional modeling. In the interaction of the student-professional diagram, the evaluation of students of the same major is aggregated to reflect the potential characteristics of the major. The third part is the integration of the two models of students and spoken English. Through the full convolutional layer learning model parameters, the matching degree calculation between the student and the recommended spoken English is performed.

$U = \{u_1, u_2, \ldots, u_n\}$ and $V = \{v_1, v_2, \ldots, v_m\}$ are the sets of students and spoken English respectively, where n is the number of students and m is the number of spoken English. We assume that $R \in R^{n\times m}$ is the student-English speaking scoring matrix, which also known as the student-English speaking graph. If candidate u_i scores spoken English v_j, then r_{ij} is non-zero, otherwise we use 0 to indicate the score of spoken English v_j by candidate u_i, that is, $r_{ij} = 0.\Gamma = \{\langle u_i, v_j\rangle r_{ij} = 0\}$ is the set corresponding to the spoken English that student u_i has not evaluated. $T \in R^{n\times n}$ represents the social graph of students, where $T_{ij} = 1$ means that u_i and u_j are closely related.

The following is a detailed introduction to the spoken language resource recommendation algorithm based on the BP deep neural network.

The purpose of building a student model is to extract the potential characteristics of students. The student model is divided into two parts: the student-English speaking picture and the social network. The two parts are described separately below.

Because a student's score on a spoken English can tell the students' preference for the spoken English, the score of the spoken English and the characteristics of each spoken English can help students model. The student spoken English graph model in this paper is based on this to integrate spoken English features and spoken English evaluation to extract potential characteristics of students.

$$x_{ia} = g_v\left(\left[q_a \oplus e_r\right]\right). \tag{1}$$

Among them, x_{ia} is the multi-layer perceptron (MLP) of students and spoken English, x_{ia} is the interactive representation of each spoken English and score, q_a is the feature vector of spoken English, e_r is the feature quantity of five evaluation levels, and $\oplus$ represents the connection of two vectors. The calculation of formula (1) combines the scores corresponding to each spoken English and each spoken English to perform feature extraction. Since there are many spoken English that each student participates in the evaluation, it is necessary to aggregate all the spoken English that the students participate in the evaluation, and we introduce an aggregation function.

$$h_i^I = \sigma\left(W \cdot \text{aggretions}\left(\left\{x_{ia}, \forall a \in C(i)\right\}\right) + b\right). \tag{2}$$

Among them, $C(i)$ is the spoken English evaluated by student $u(i)$, W and b are the weights and biases of the neural network, and σ is the Relu activation function. The most common aggregation function is to directly aggregate the multiple spoken English evaluated by each student, that is, formula (3).

$$h_i^l = \sigma\left(W \cdot \left\{\sum_{a\in C(i)} \alpha_i x_{ia}\right\} + b\right), \tag{3}$$

$$\alpha_i = \frac{1}{|C(i)|}. \tag{4}$$

However, because the weight of each spoken English is different for students, the average aggregation cannot be directly calculated. In order to make up for the lack of average aggregation, the attention mechanism is introduced.

$$h_i^l = \sigma\left(W \cdot \left\{\sum_{acc(i)} \alpha_{ia} x_{ta}\right\} + b\right), \tag{5}$$

α_{ia} is the weight of the attention mechanism.

$$\alpha_{ia}^* = w_2^T \cdot \sigma\left(W_1 \cdot \left[x_{ia} \oplus p_i\right] + b_1\right) + b_2, \tag{6}$$

$$\alpha_{ia} = \frac{\exp\left(\alpha_{ia}^*\right)}{\sum_{a\in C(i)} \exp\left(\alpha_{ia}^*\right)}. \tag{7}$$

Among them, p^i is the feature vector of student u_i, and the interaction of spoken English and scoring is connected with the feature vector of the student. w_2^T, b_1, b_2 and W_1 are weights and biases, and the Softmax function is use to normalize the above attention weights to get the final attention weights. It can be understood as the contribution of interaction to the latent factors of the student-English speaking space. After the calculation of formula (1)-(7), we extracted the potential features of each student in the structure of the student-English speaking graph. The potential characteristics of students will also be reflected in the social relationships of students. Therefore, we introduce the student social network model to extract potential features.

This paper compares students as users, and oral English as projects, and compares students' class relationships to users' social networks, and establishes a model of oral English recommendation based on students' social interactions. In view of the fact that the social relationship of students will affect the students' choice of spoken English, the influence communication layer is introduced into the social recommendation network. The following is an improved social network model, as shown in Figure 1.

The characteristics of each student are divided into potential characteristics and obvious characteristics. Obvious characteristics can be reflected by students' evaluation of spoken English, and latent characteristics are reflected by students' social relationships. Therefore, we set up latent features, perform free embedding on the latent features of students, and continuously update the latent features through social relationship fusion.

$$\text{embedding} = nn \cdot \text{Embedding}(n, d). \tag{8}$$

The input of the fusion layer is the apparent feature vector and latent feature vector of each student. The two feature vectors are fused, and the fully connected layer is used for feature extraction. At this time, the output h_i^0 is the entire feature of the student.

$$h_i^0 = g\left(W^0 \times \left[p_i, m_i\right]\right). \tag{9}$$

Among them, W^0 is the weight matrix, $g(.)$ is a fully connected layer, p_i is the potential feature of the student, and m_i is the obvious feature.

The influence propagation layer is shown in Figure 2. Among them, the green node represents the current node u_i, the gray node is the first-order neighbor node of the current node, and the red node is the current node is the neighbor node of the first-order neighbor node.

Due to the change of time, the influence in social networks is spreading. For the current node u_i, h_i^0 is the input of the fusion layer, and h_i^1 is the feature obtained by averaging the first-order neighbor nodes (all gray nodes) of the current node u_i. At this point, the current node has the characteristics of the four neighbor nodes on the blue background. h_i^2 is the first-order neighbor node of the first-order neighbor (the result of the fusion of the red node, and it can be seen that the node u_i at this time has the characteristics of all the nodes in the green background) is also the feature of average fusion. Therefore, if h is the student's feature vector after impact diffusion, $S(i)$ is the set of neighborhood nodes of student u_i, and h_b^{k-1} is the neighborhood node feature of student u_i after $k-1$ social networking. Through the feature fusion of the neighboring nodes after $k-1$ times of social network influence, the characteristics of student u_i are obtained as:

$$h_i^k = \text{pool}\left(h_b^{k-1} b \in S_i\right), \tag{10}$$

$$\text{pool}\left(h_b^{k-1}\right) = \sum_{b\in S(i)} \frac{1}{|S(i)|} h_b^{k-1}. \tag{11}$$

The social network and the student-English speaking graph provide the characteristics of the student from different angles. Therefore, in order to extract all the potential characteristics of the student, it is necessary to combine the student-English speaking graph model and the social network model.

$$c_1 = \left[h_i^l \oplus h_i^k\right], \tag{12}$$

$$c_2 = \sigma\left(W_2 \cdot c \frac{n!}{r!\,(n-r)!} \frac{n!}{r!\,(n-r)!_1} + b_2\right), \tag{13}$$

$$h_i = \sigma\left(W_l \cdot c_{l-1} + b_l\right). \tag{14}$$

Among them, the output h_i is a combination of the potential features of the student-English speaking graph model and the social network model, and the student features are extracted through the full convolutional layer.

Just like the student model, in order to learn the latent features of spoken English, the spoken English model aggregates the evaluations of students who select the same spoken English to reflect the latent characteristics of spoken English.

$$f_{jt} = g_u\left(\left[p_l \oplus e_r\right]\right). \tag{15}$$

Among them, f_{jt} is the potential feature of spoken English after connecting the feature vector of student t and the feature vector corresponding to the score, and extracted by the full convolution layer. Since there is more than one student participating in the evaluation of spoken English, it is necessary to aggregate all the students who evaluate the spoken English, and for this purpose, the student's aggregation function is designed.

$$z_j = \sigma\left(W \cdot \text{aggre}_{\text{users}}\left(\left\{f_{jt}, \forall t \in B(j)\right\}\right) + b\right). \tag{16}$$

Considering that each student has different meanings for extracting the potential features of spoken English, the fusion function needs to introduce an attention mechanism to give students who choose the same spoken English different weights.

$$\mu_{jt}^{*} = w_2^T \cdot \sigma\left(W_1 \cdot \left[f_{jt} \oplus q_j\right] + b_1\right) + b_2, \tag{17}$$

$$\mu_{jt} = \frac{\exp\left(\mu_{jt}^{*}\right)}{\sum_{t\in B(j)} \exp\left(\mu_{jt}^{*}\right)}, \tag{18}$$

$$z_j = \sigma\left(W \cdot \left\{ \sum_{EB(j)} \mu_{jt} f_{jt} \right\} + b\right). \tag{19}$$

Among them, z_j is the potential feature of spoken English extracted by the aggregation function after introducing the attention mechanism.

The recommendation algorithm of spoken English is simply to match the characteristics of the students with the characteristics of the spoken English. Proved that the fully connected layer can fit arbitrary functions. Therefore, we choose to use multiple full convolutional layers to learn the similarity function between students and spoken English features.

$$g_1 = \lfloor h_i \oplus z_j \rfloor. \tag{20}$$

Among them, h_i is the latent feature of the student, z_j is the latent feature of spoken English, and $\oplus$ means connecting the two vectors.

$$g_2 = \sigma\left(W_2 \cdot g_1 + b_2\right), \tag{21}$$

$$g_{l-1} = \sigma\left(W_l \cdot g_{l-1} + b_l\right), \tag{22}$$

$$r_{ij}' = w^T \cdot g_{l-1}. \tag{23}$$

Among them, l represents the number of hidden layers, and r_{ij}' represents the matching degree of student u_i to spoken English v_j.

The above process is to perform feature extraction of multiple fully connected layers (MLP) on the result of the splicing. Finally, the obtained feature matrix is mapped to a one-dimensional vector, that is, the predicted value of each spoken english.

The loss function of BP deep neural network based on social recommendation is:

$$\text{Loss} = \frac{1}{2|O|} \sum_{i,j\in O} \left(r_{ij}' - r_{ij}\right)^2. \tag{24}$$

Among them, O is a set of tuples (i, j), where tuples represent student u_i and graded spoken English v_j. Therefore, this loss function is to calculate the loss for all scoring spoken English. For the spoken English without scoring, the loss is not considered, and the L2 loss function. When the predicted value is significantly different from the original value, the loss penalty is too large. When the gradient descent method is used to solve the problem, the gradient is large, which may cause the gradient to explode.

Therefore, we smoothed the L2 loss function and chose the Smooth Loss loss function. The function is as follows:

$$\text{Smooth Loss} = \begin{cases} \lambda\left(x - x'\right)^2, & \left|x - x'\right| < 1, \\ \left|x - x'\right| - \lambda, & x - x' < -1,\ x - x' > 1. \end{cases} \tag{25}$$

It can be seen that when $x - x'$ is less than 1, there is only one parameter λ difference from the original second order. However, when the absolute value of $x - x'$ is large, compared with the original L2 loss function, the Smooth loss function reduces the loss penalty and becomes a first-order loss. Therefore, using the Smooth Loss function can reduce the proportion of outliers and alleviate the model's deviation to the outliers compared to using the L2 loss function.

In order to prove the basis for the selection of the loss function, we conducted experiments on common loss functions and compared the commonly used loss functions in the recommendation system. For the MSE loss function, Exp exponential loss function, and Smooth loss function with different parameters, according to experiments, it is found that when the parameter in the Smooth loss function is 0.6, the MAE calculation results, RMSE calculation results, and accuracy are the best.

$$\text{Smooth Loss} = \begin{cases} \lambda\left(x - x'\right)^2, & \left|x - x'\right| < 1, \\ \left|x - x'\right| - \lambda, & x - x' < -1,\ x - x' > 1, \end{cases} \tag{26}$$

$$\text{MSE}(y, \hat{y}) = \frac{1}{n} \sum_{i=1}^{n} \left(y_i - \hat{y}_i\right)^2, \tag{27}$$

$$\text{loss}\left(y, y'\right) = \exp\left(-yy'\right). \tag{28}$$

4. Research on application of multimedia in spoken English training based on BP deep neural network

The voice part of the audio can be detected and extracted to enter the text-to-speech alignment process. For the sake of continuity, this paper first analyzes and discusses the forced alignment algorithm based on Viterbi decoding. On this basis, this paper proposes an improved fault-tolerant alignment algorithm based on extended matching network. Moreover, this paper presents a detection method for insertion, deletion, and replacement errors at the word and phrase level, and a larger-scale dynamic alignment algorithm for sentence level. Figure 3 shows the basic flow of text-to-sentence matching of a single sentence.

This paper uses the matching network shown in Figure 4 to extend the search network of the traditional forced alignment algorithm, so as to achieve a fault-tolerant mechanism at the word and phrase level. SIL stands for silent model, OOV stands for garbage model.

This article further discusses how to provide a solution based on the idea of dynamic programming for the alignment of continuous corpus and incomplete matching corpus on a large scale (sentence level). The overall steps of the algorithm are shown in Figure 5.

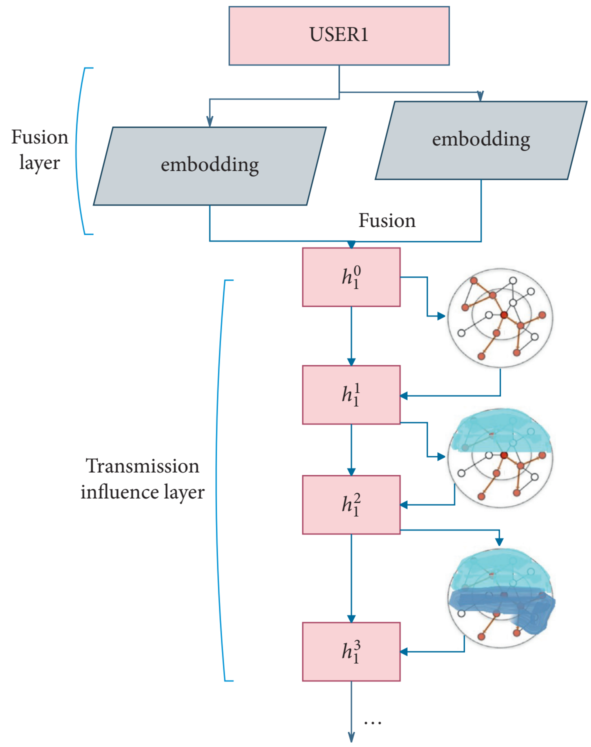

Figure 1: Improved social network model

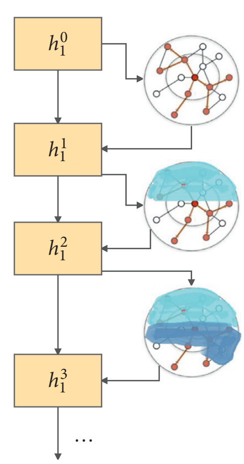

Figure 2: Influence propagation layer

Due to insertion, deletion, and replacement errors, not all models in the matching process can have corresponding nodes, especially the context-dependent HMM model (TRIPHONE) located at the word boundary. In the TRIPHONE model corresponding to syllable K as shown in Figure 6, since the word YOU is skipped during matching, the corresponding TRIPHONE model changes from <NG-K-Y> to <NG-K-V>. Therefore, in addition to comparing the corresponding nodes, it is also necessary to compare the word boundaries to prevent the expansion of the search subspace caused by some models in the second stage of matching because they cannot find the corresponding nodes.

The system front-end is based on the standard algorithm for feature extraction of the distributed speech recognition front-end of the European Telecommunications Standards Agency as shown in Figure 7. In order to ensure sufficient accuracy of the front-end features, a single-frame amplitude normalization technology is applied to make full use of the processing length of the processor to make the accuracy of fixed-point operations meet the requirements of the back-end recognition engine.

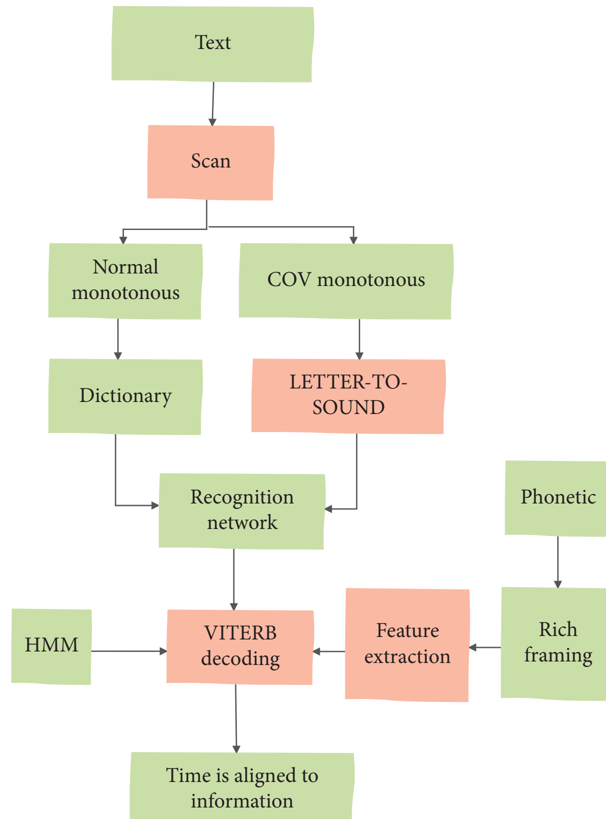

FIGURE 3: Flow chart of text-language matching.

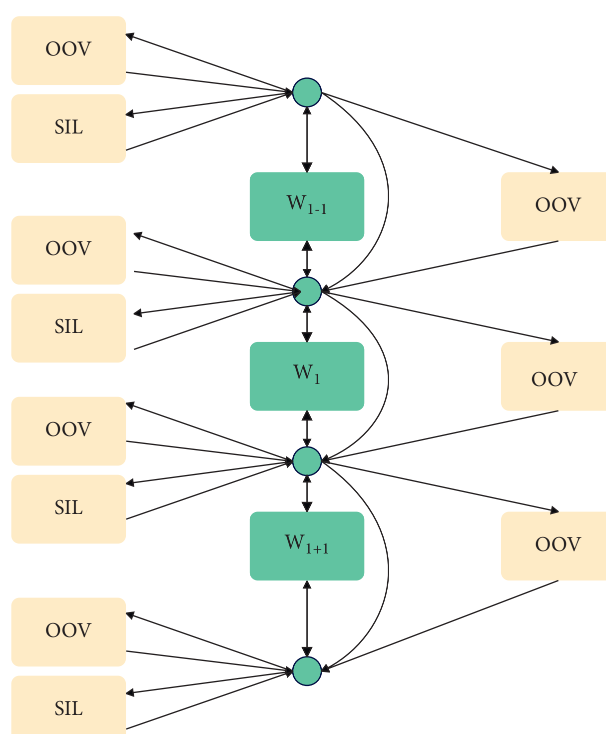

FIGURE 4: Extended network of fault-tolerant alignment algorithm.

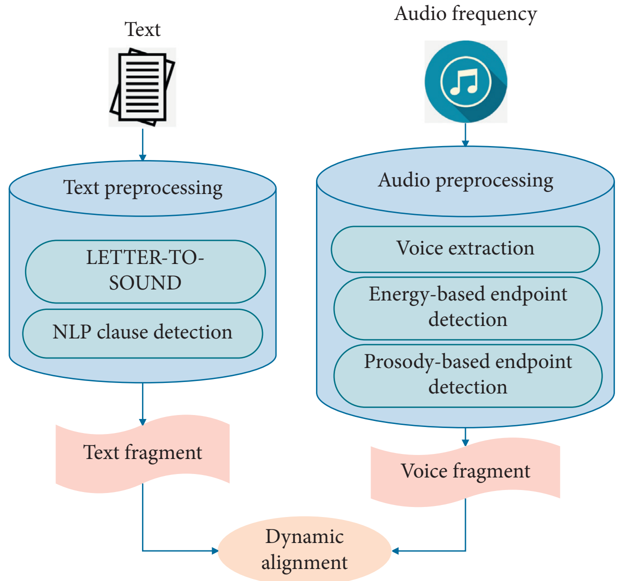

Figure 5: The flow of the alignment algorithm for a large number of continuous non-exact matching corpora.

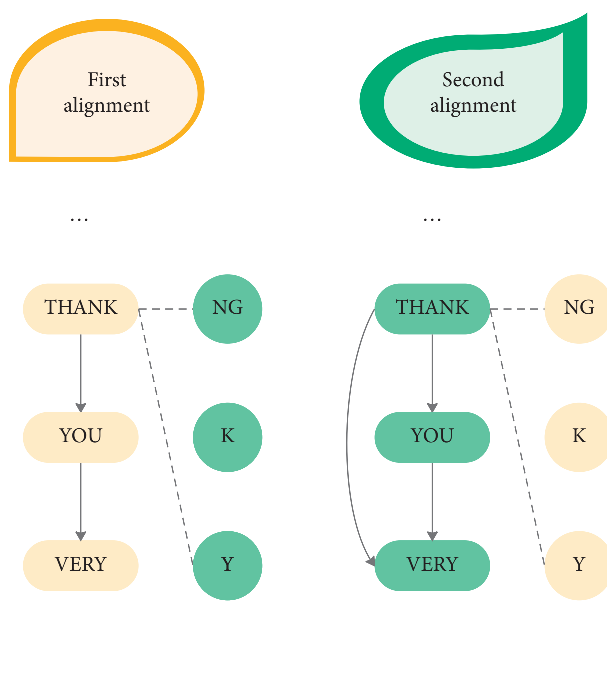

Figure 6: TRIPHONE changes in word boundaries caused by errors.

Figure 8 shows a schematic diagram of the voice processing flow of the system.

The modules of the speech recognition system include five parts: feature value extraction, phoneme recognition, phoneme association, pronunciation evaluation, and error detection. The speech recognition module is shown in Figure 9:

The external function realizes the visual window. The example sentence library view is played according to the specified example sentence or learning strategy. The information view displays sentences and phonetic symbols, displays monophony scores and corrections, displays sentence prosody scores and corrections, and plays corrections. The user management interface displays the user's transcripts, study files, and analyzes easy-to-mispronounce phonemes and common errors. The system can recognize English learners with a strong Chinese accent.

This paper conducts training research on the model of this paper, and the results are shown in Figure 10 below. It can be seen from Figure 10 that the student's speech

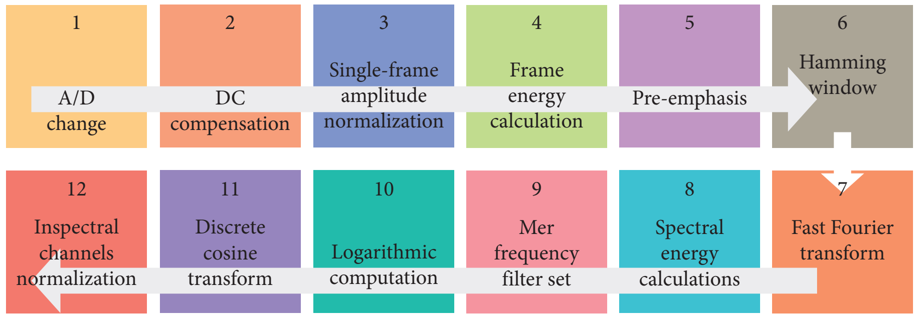

Figure 7: Front-end processing flow of text matching engine.

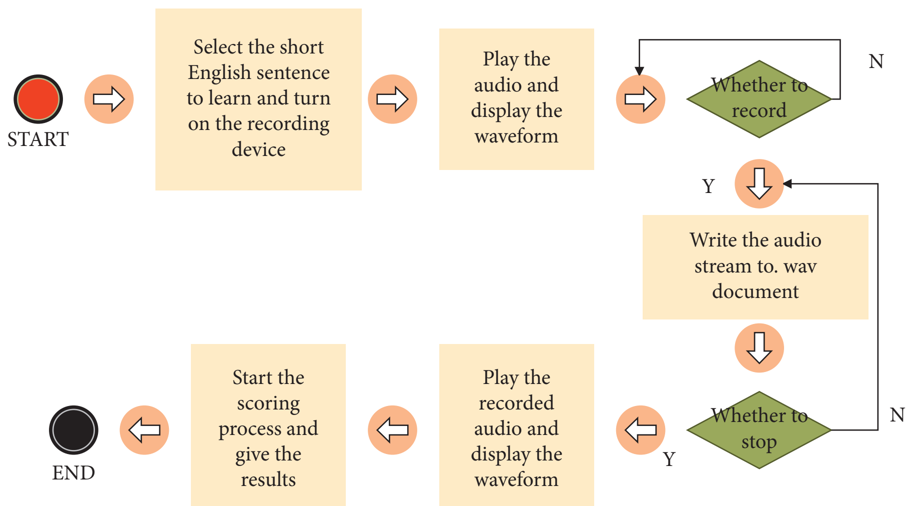

Figure 8: Schematic diagram of system processing.

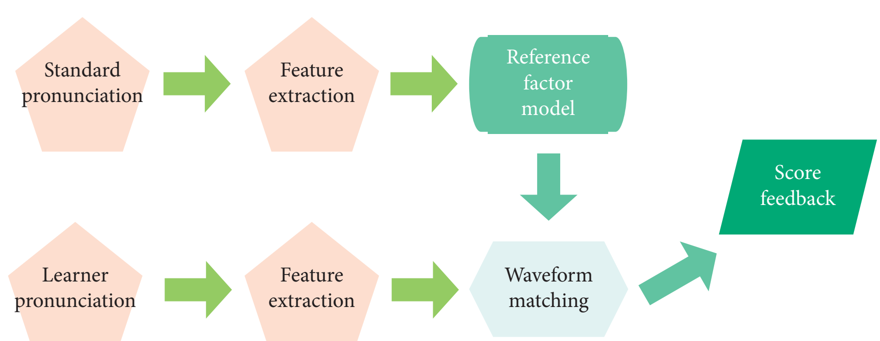

Figure 9: Schematic diagram of the speech recognition module.

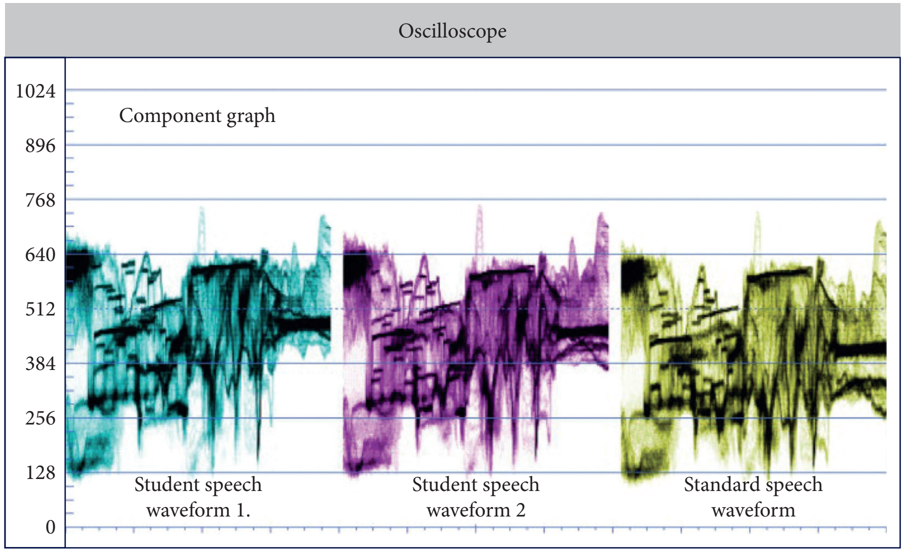

Figure 10: Comparison of speech waveforms in spoken English training.

Table 1: Test data of spoken English training.

Number	Training effect	Number	Training effect	Number	Training effect
1	79.95	13	79.23	25	80.87
2	86.17	14	91.71	26	89.86
3	86.92	15	89.46	27	88.14
4	86.96	16	79.26	28	84.91
5	81.40	17	89.62	29	88.07
6	88.60	18	83.92	30	86.97
7	86.94	19	83.53	31	93.84
8	90.22	20	81.77	32	80.81
9	84.05	21	89.08	33	88.86
10	81.89	22	83.90	34	80.04
11	87.04	23	87.65	35	84.74
12	91.89	24	90.66	36	82.48

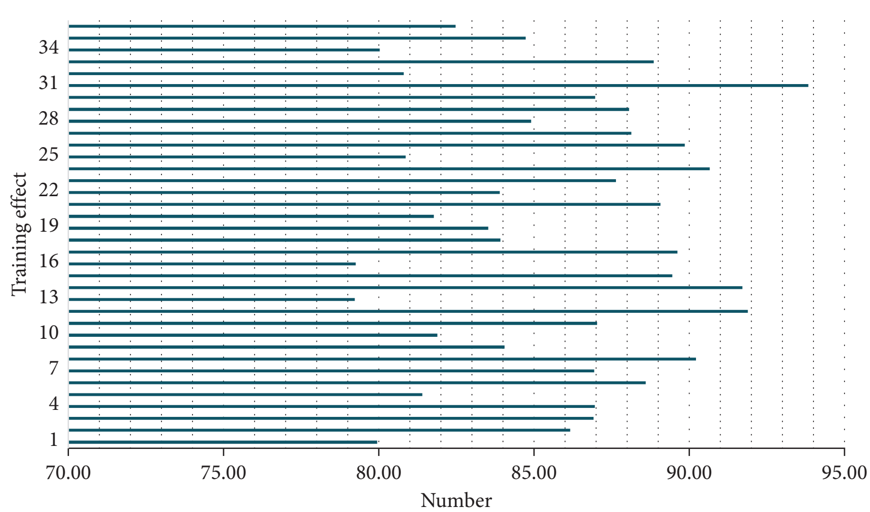

Figure 11: Evaluation of the training effect of spoken English.

waveform is similar to the standard speech waveform, which means that the student's spoken English h training is very effective and the student's spoken English is very standard.

On the basis of the above analysis, the effect of the spoken English training of this system is evaluated, and the results shown in Table 1 and Figure 11 below are obtained.

It can be seen from the above research that the multimedia based on BP deep neural network proposed in this paper has a good effect in the application research of spoken English training, and can effectively promote the effect of spoken English training of students.

5. Conclusion

In recent years, with the continuous advancement of new curriculum reforms, it is required to pay great attention to spoken English teaching. Although oral teaching has been improved to a certain extent compared with the previous teaching, it is still difficult to achieve the purpose of effectively training students' oral skills, which seriously affects the improvement of students' oral communication skills. The current intelligent spoken English learning system needs to provide functions such as recognition of the user's pronunciation, comparison with expert pronunciation, and error correction. The basis of all these functions is speech recognition. The accuracy of speech recognition and the robustness of the recognition algorithm will directly determine the overall performance of the learning system. This paper combines the BP deep neural network algorithm to construct the spoken English training system, improves the intelligent effect of spoken English training, and evaluates the performance of the system through experimental research. The experimental research results show that the multimedia based on the BP deep neural network proposed in this paper has a good effect in the application research of spoken English training, and can effectively promote the effect of spoken English training of students.

Data Availability

The labeled dataset used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no competing interests.

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Research Article

A Mental Disorder Prediction Model with the Ability of Deep Information Expression Using Convolution Neural Networks Technology

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The psychological health education work of all universities is currently facing the same problem, despite the rapidly expanding scale of universities and the ever-increasing demand for students: there are few teachers engaged in this field, who cannot meet the urgent needs of the majority of students. Because of their mental illness, university students are unable to complete their studies in a timely manner, affecting their own development. One after the other, such occurrences occur. This paper uses the common mental disorder identification of university students as an example and builds a mental disorder identification model based on CNN. The model has the ability to learn on its own, allowing it to diagnose psychological disorders in university students and provide support for college psychological counselling and the psychological health team. However, because China currently pays little attention to the psychological health of this population, it is necessary to investigate and analyse the psychological health of university students at this time.

1. Introduction

Many people are experiencing varying degrees of psychological barriers as a result of increasing pressure from all directions in society, family, and life. Social stability, family harmony, and happiness have all suffered as a result of psychological obstacles [1]. The psychological health education work of all universities is currently facing the same problem, despite the rapidly expanding scale of universities and the ever-increasing demand for students: there are few teachers engaged in this field, which cannot meet the urgent needs of the majority of students [2]. The severe shortage of full-time psychological counsellors in universities has become a major impediment to psychological health education and intervention. According to the analysis of the factors affecting the psychological health of contemporary university students, we can summarize it into 10 influencing factors: personal future pressure, social pressure, economic pressure, environmental adaptation pressure, study pressure, emotional pressure, parental expectation pressure, family influence pressure, professional emotional pressure, and interpersonal pressure. We must take seriously the psychological health problems of university students, fully analyse and study the causes of university students' mental problems, and understand the factors affecting psychological health. Starting at the source, using effective approaches to detect early warning indications of psychological issues in order to reach the goal of prevention, to truly solve the problem of university students' psychological health, suffocate the emergence of psychological problems in the cradle. The development of artificial intelligence theory brings opportunities to computer-aided mental disorder identification [3]. The modeling and prediction of psychological disorders can help relevant experts and scholars understand the changing characteristics of psychological disorders and formulate relevant treatment plans for patients with psychological disorders. Therefore, the prediction of psychological disorders has very important social and practical application value.

People used experts to predict psychological disorders at first. In this method, the predicted outcomes of psychological disorders are insecure. Different experts can produce different forecast outcomes, and forecast outcomes are closely related to expert knowledge, making psychological disorder forecast outcomes highly subjective and unreliable [4]. They are exceptional young college students who represent the educated youth [5]. Many studies in the literature have shown that NN can effectively model and predict time series. This paper analyses the reasons affecting the psychological health of Chinese university students, expands the evaluation factors, collects the corresponding data, uses the convolution NN model to predict and analyse the psychological health of university students, and establishes a convolution NN forecasting model suitable for the identification of mental disorders, based on the current situation and characteristics of Chinese students.

Currently, universities only offer consultation and guidance in the field of psychological health education to university students through school psychological counselling teachers or hospital psychological experts. However, due to varying levels of experience and skill, it is unable to produce the desired effect. The NN expert system can perform complex pattern recognition and tasks with complex rules that cannot be predicted ahead of time. They are under significantly more psychological stress than their peers. As a result, research into the psychological well-being of today's university students is critical. In order to cope with psychological health demands in the future, researchers are looking into the internal law of numerous aspects affecting psychological health. This helps to generate new ideas for psychological health work. This paper developed a CNN-based [6] psychological disorder identification model. The error between the predicted outcomes and the measured value output by the ANN [7] is small after sample training, and the expected effect is well achieved. The model can detect university students' psychological status and provide diagnosis results in real time, as well as providing support for psychological consultation and psychological health teams in universities.

2. Related Work

Psychological health education in foreign universities is divided into three stages, according to literature [8]: initial stage, development stage, and mature stage. According to statistics in literature [9], university students who have dropped out of school due to various mental disorders caused by mental illness account for about half of all dropouts. Literature [10] combines knowledge discovery and NNs to produce forecast results that outperform traditional methods. A survey of 140 medical graduate students was conducted in literature [11]. It was discovered that the range values of various factors among major students differ significantly from the national average and that some factor scores are lower than those of ordinary people. The single factor analysis method is used to analyse related factors in literature [12] in the research of postgraduates' physical and mental symptoms. Social factors such as gender, whether they are an only child, and personality traits have been shown to influence graduate students' physical and mental symptoms in studies. Literature [13] surveyed postgraduates, showing that the psychological health of female postgraduates is significantly higher than that of male postgraduates in terms of both factor scores and the total score of the scale. In literature [14, 15], with the help of the idea of quadratic performance index in optimal control, it is proposed to use quadratic performance index to calculate the control law to obtain the desired optimization effect. Literature [16] mentioned that, with social changes and the influx of only children into universities, the number of university students suffering from psychological disorders had shown a clear upward trend. Literature [17] conducted a survey of 400 medical graduate students in Chengdu and found that the suicide probability of girls was 78.99%, while that of boys was only 58.60%. In literature [18], a survey of 289 medical master's students in a military school was grouped by gender, and the grouping results were compared with several domestic research results. The comparison shows that female students are higher than male students in some factors. Literature [19] proposed a hybrid learning algorithm that alternately uses a genetic algorithm and CNN algorithm. In literature [20], 828 postgraduates on campus are taken as the research objects regarding the personality differences of graduate students and the differences in their living conditions. Through discussion, it is found that some factors of the graduate student population are higher than the national norm range value. Due to the differences in the personality of this group, psychological health presents the phenomenon of "three highs" and "three lows." Literature [21] proposes to combine multiple population genetic algorithms with NNs, which can simultaneously consider global optimization solutions and local optimization solutions. Literature [22] uses NNs to establish mathematical models to solve practical problems. Literature [23] first applied the support vector machine model to time series forecasting in 1997. Literature [24] verifies the prediction effect of support vector machines on five financial time series data. The experimental results show that the evaluation indicators such as the prediction mean square error and the average absolute error on the five data samples of the support vector machine are better than the backpropagation NN. Literature [25] survey on university students across the country shows that 22.01% of the students have obvious psychological problems, and about 3/8 of the students have different degrees of psychological obstacles. Literature [26] proposed an NN forecasting model with lower complexity in 2009. In this paper, according to the current psychological health status of university students, a prediction system model of psychological health status of university students is established based on CNN. This model has high precision and high efficiency. Students' psychological problems can be predicted in advance, and corresponding measures can be taken in time. Finally, the stability and unity of the school and the growth of students will be realized.

3. Mental Disorder Prediction Based on CNN

3.1. NN Algorithm. In the field of computer science and artificial intelligence, artificial neural network (ANN) simulates the information dissemination mechanism of the biological nervous system so that the machine can imitate the human brain to learn and recognize information [27]. NNs perform calculations and spread information through a large number of interconnected neurons. They are commonly used to describe the complex relationship between input and output, as well as investigate data's internal structure and patterns. The topological structure of ANNs' connections, as well as the strength of synaptic connections or connection weights, determines their functional characteristics. A matrix W can be used to represent the weights of all NN connections. Its entirety reflects the NN's knowledge storage for the problem at hand. Through the learning and training of samples, the NN can continuously change the connection weight and topology of the network, bringing the network's output closer to the desired output. The dynamic adjustment of variable weights is the essence of this process, which is known as NN learning or training.

Artificial neuron is a simulation of the characteristics of weighted summation of the input information of biological neuron. It uses the activation function to map the obtained network input to realize the processing of amplifying or suppressing the output value of the neuron. Assuming that the n inputs of a neuron are represented by $x_1, x_2, \ldots, x_n$, the connection weight corresponding to each input is $w_1, w_2, \ldots, w_n$, the threshold is represented by θ, and the actual output value of the neuron is represented by y, then the input-output mapping relationship can be represented by the following formula:

$$y = f\left(\sum_{j=1}^{n} w_j x_j - \theta\right). \tag{1}$$

Here, f is called the activation function. Figure 1 shows the structure of a single artificial neuron computer system.

The learning method of CNN is the third major factor that determines the information processing performance of CNN, so the study of learning plays an important role in NN research [28]. Rules that change the weights are called learning rules or learning algorithms. When a single processing unit collectively adjusts the weights, the network shows "intelligent" characteristics. Meaningful information is distributed and stored in the adjusted weight matrix.

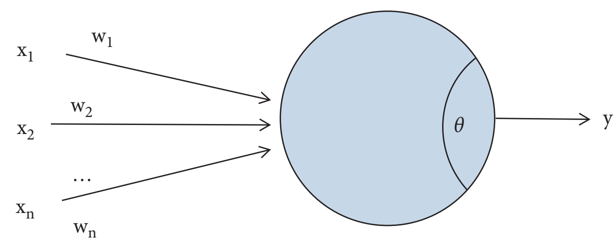

Figure 1: Artificial neuron.

3.2. The Evaluation Model of University Students' Psychological Health Status. The preparation of the data shows a very positive role in ANN. Good data can quickly balance the convergence of the network, and it is close to the output result. On the contrary, bad data, no matter how to modify the network parameters, cannot make the network achieve the required effect. Taking the identification of common psychological diseases of university students from five characteristics as an example, the development process of model service is illustrated. The five characteristics of input include behaviour, emotional state, diet and sleep, personality characteristics, and physical diseases. Four common mental diseases of university students are selected as training, and an NN for identifying mental diseases is constructed. In practice, the features of mental illness are much more complicated and huge, and there are many overlapping interactions among the features. Here, only five distinctive commonalities are selected to construct the training set of NN recognition.

The improved NN psychological barrier forecasting model works on the following principle. To begin, gather historical data on psychological barriers. The chaos algorithm is then used to preprocess historical data on psychological disorders in order to better understand how their characteristics change over time. Finally, NN is used to learn preprocessed historical data of psychological disorder, and the particle swarm optimization algorithm is used to improve NN's existing problems and establish the best psychological disorder forecasting model. Figure 2 depicts the working principle of the improved NN-based mental disorder forecasting model.

The period in which college students live is a critical transition period for a person to mature. During this period, they will face many problems such as emotion and going to the society. If not handled properly, various psychological problems will appear, such as depression and anxiety. Convolution layer uses local connection and weight sharing to reduce the number of network-free parameters and the complexity of network parameters. The convolution layer calculation formula is as follows:

$$X^{(l)} = f\left(W^{l} \otimes X^{(l-1)} + b^{(l)}\right). \tag{2}$$

Here, $X^{(l)}$ and $X^{(l-1)}$ represent the neuron activity of layer l and l-1, W^l represents the convolution kernel, and b represents the bias.

In order to make the training of NN more effective and improve the training speed of the established NN, the input and output data of NN should be preprocessed first. For NN calculation, it is necessary to convert literal concepts into numerical values. In order to facilitate the discrimination of data, six-dimensional vector values are used to represent each feature. The first three bits represent categories, and the last three bits represent features, so a total of 26 = 64 features can be accommodated. The outputs of the four subconvolution networks are fused in the full connection layer. The dimensions of the first full connection layer and the second full connection layer are 512 and 256, respectively. Finally, the Softmax function is selected as the output classifier. The Softmax function estimates the probability that input x belongs to a specific category $j \in \mathrm{k}$:

$$P(y = j \mid x) = \frac{\exp\left(x^T W_j\right)}{\sum_{k=1}^{K} \exp\left(x^T W_k\right)}. \tag{3}$$

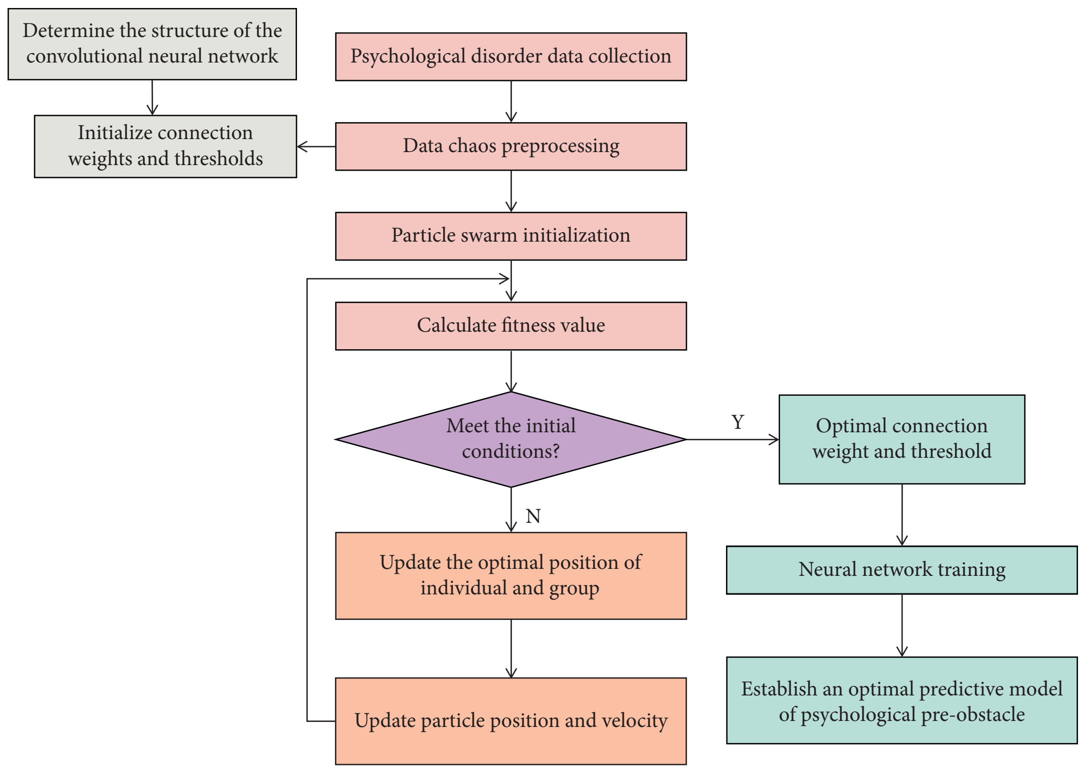

Figure 2: The working principle of the psychological disorder forecasting model of the improved NN.

Select the commonly used Rectified Linear Units (ReLU) as the excitation function. The ReLU excitation function can prevent gradient disappearance and overfitting. The ReLU excitation function is defined as

$$f_{\text{cov}}(x) = \max(0, x). \tag{4}$$

Dropout is an effective means to prevent overfitting and improve the effect in CNN. The feature representation of data is very important to the successful training of the model. Better data representation can reduce or even eliminate the influence of factors unrelated to the training task in the original data on the training results and save useful information that is beneficial to the training task.

The characteristics of each influencing factor are sorted according to the degree of psychological resistance, the index of the category affected by each influencing factor in the initial mental performance state is obtained, and the mental performance state of different influencing categories is obtained. For m-dimensional college students' psychological complexity, the total number of different mental performance state sequences is m, the probability of k different mental performance state sequences is assumed to be $P_1, P_2, \ldots, P_k$, and the probability of the mental state sequence is ranked. Define permutation entropy:

$$H_{PE}(m) = -j = 1\sum^{k} P_j In P_j. \tag{5}$$

Integrate the state sequence given by (5), and use (6) to express the emotional characteristics of behaviour corresponding to the mental state at this stage:

$$0 \leq H_{PE} = \frac{H_{PE}}{In(m)} \leq 1. \tag{6}$$

Suppose that $\{x(t), t = 1, 2, \ldots, N\}$ represents the time series set of behavioural emotional characteristics of college students' mental state. Due to the complexity of the behavioural tendency of college students dominated by psychology, it is necessary to construct a relationship with the psychological duration τ, select the duration sequence $x(t+\tau)$ to form a new duration point sequence $y(t)$, and determine it according to the correlation between the calculation of $x(t)$ and $y(t)$ and psychological duration τ.

This paper uses the prevalence of mental disorders as historical data of mental disorders. They compose a kind of time series data according to the chronological order, without considering related influencing factors, so that the historical data composes a one-dimensional time series data. In order to obtain a higher-precision mental disorder prediction structure, an improved NN mental disorder forecasting model is proposed. This model has the ability of autonomous learning and can realize the diagnosis of university students' psychological disorders.

4. Result Analysis and Discussion

Researchers simulated the computing power of real NN to create NN. Because it gradually demonstrates powerful functions such as learning, memory, and association during its development, NN is widely used in a variety of fields. Simple pattern recognition is realized through NN application research in the diagnosis of university students' psychological disorders, and the expected diagnosis effect is achieved. Currently, the system is just a simple simulation of a specific biological nervous system performance. The system can theoretically perform complex pattern recognition and complete tasks with complex rules that cannot be determined in advance if enough training and learning are done. The internal representations used by the neural network after learning the sample set are the weights and thresholds that can best meet the data requirements obtained by the neural network through adaptive learning. The feature data from the sample set to be identified is then fed into the trained network, which can then reason and identify the sample output results automatically. When viewed as a mapping from input data to output data, the neural network is highly nonlinear. Figures 3–6 show the results of the experiments.

It can be seen that no matter whether the input sample length is 20 or 30 when the convolution layer and downsampling layer are 1, the root mean square error and correlation coefficient of the forecast outcomes are better than when the convolution layer and downsampling layer are 2. The determination coefficient of the forecast outcomes is closer to 1. In this paper, it is considered that it is more reasonable to choose 1 for convolution layer and downsampling layer of convolution NN exchange rate forecasting model.

According to the degree of psychological resistance, the characteristics of each influencing factor are sorted, the indicators of the categories affected by each influencing factor under the initial mental performance state are obtained, and the mental performance states of different influencing categories are obtained. A single neuron can only perform very simple functions. If you want to realize the functional simulation of the human brain NN and complete complex tasks, you need to connect a large number of neurons in a certain way to form an ANN with different topological structures. We use the train() function to train the CNN model. The error curve after training is shown in Figure 7.

According to the graph description, it can be seen that, during the self-learning process of the network, the error is constantly decreasing, and the error basically reaches the target at Step 780. Through the continuous training of NN, the network can basically achieve the minimum error prediction. It can be seen that the forecasting model has a good prediction effect. Through the continuous training of NN, the network can basically achieve the minimum error prediction and thus can meet our needs. The comparison curve between the forecast outcomes and the true value for 2020 is shown in Figure 8.

Through the simulation test of several groups of data, it can be seen that the error between the predicted results and the true values of each group is very small, and the fitting degree of the input data basically meets the required requirements. It shows that the established model has certain accuracy and can fully predict the psychological health of university students.

The same parameters are used for the three subconvolution networks with dynamic input data. To extract the characteristics of each user's behaviour at different time points, the first convolution layer selects 64 convolution kernels with a size of 13. Following the convolution layer is the pooling layer, which is responsible for secondary feature

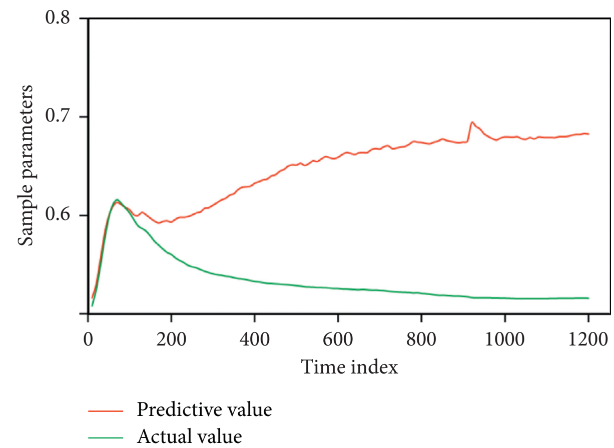

Figure 3: The forecast outcomes with the input sample length being 20 and the number of convolutional layers being 1.

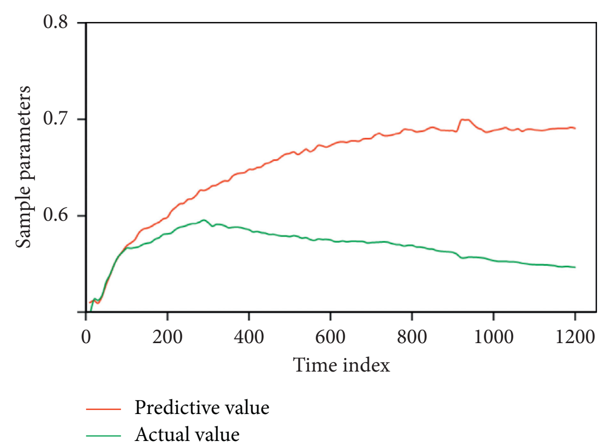

Figure 4: The forecast outcomes with the input sample length being 20 and the number of convolutional layers being 2.

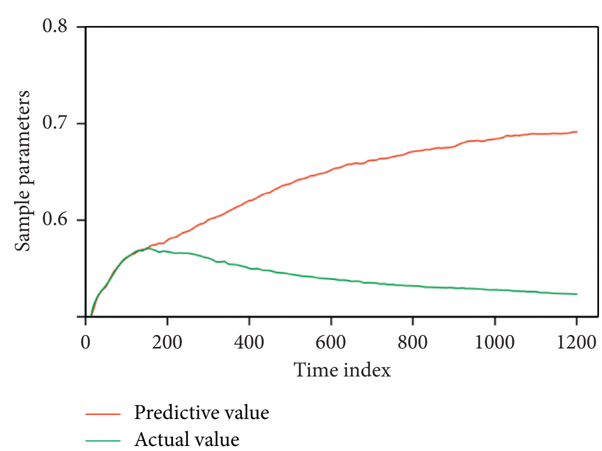

Figure 5: The forecast outcomes with the input sample length being 30 and the number of convolutional layers being 1.

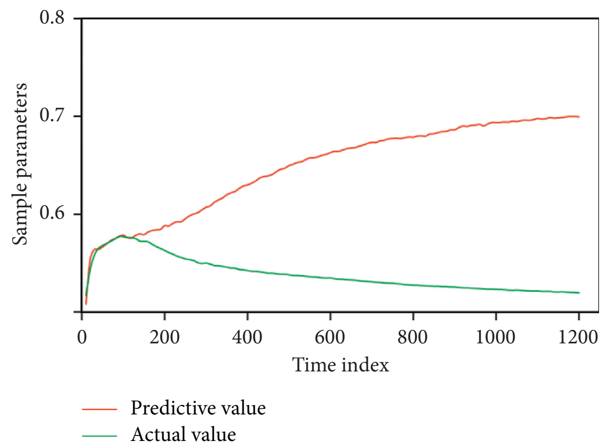

FIGURE 6: The forecast outcomes with the input sample length being 30 and the number of convolutional layers being 2.

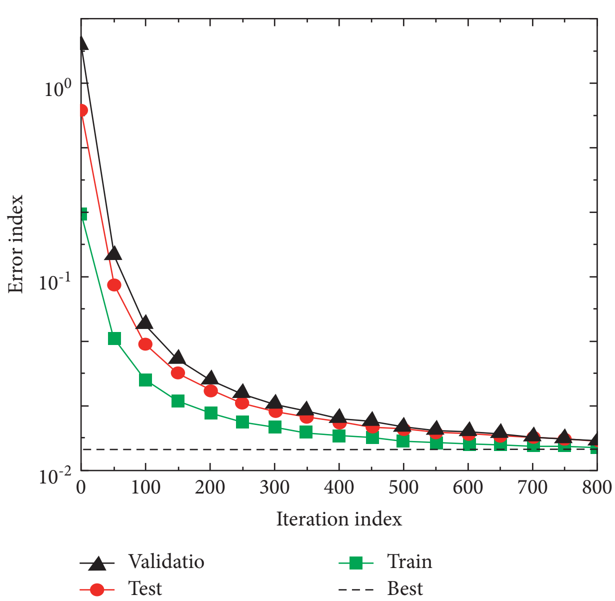

FIGURE 7: NN training process.

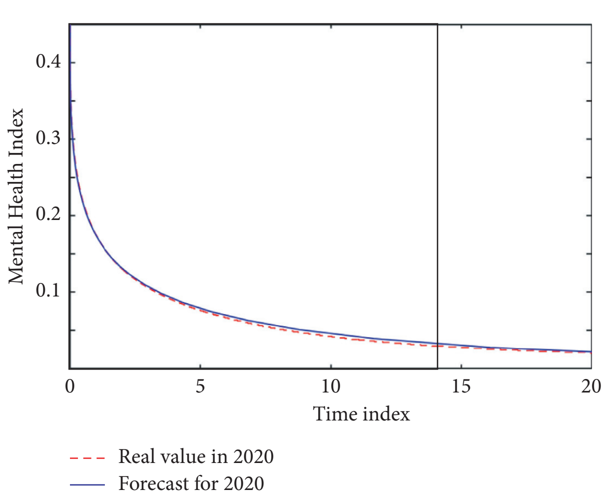

FIGURE 8: Comparison between predicted and real values of psychological health factors in 2020.

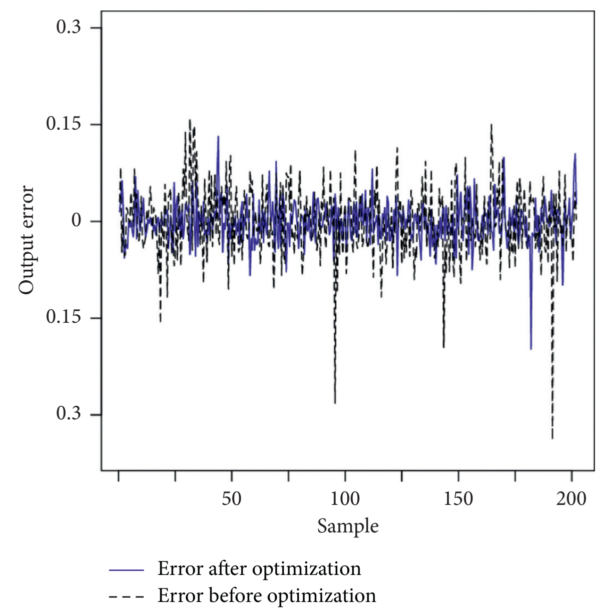

FIGURE 9: Error comparison before and after optimization.

extraction. Choose the most efficient pooling method. After the pooling layer, the second convolution layer is connected, and 128 convolution kernels with a size of 33 are chosen. The goal is to extract the characteristics of each user behaviour index at various time points, as well as the characteristics of multiple user behaviours at the same time. After the second convolution layer, a pooling layer is added. A convolution layer and a pooling layer are used to extract features from static input data. The convolution layer employs 64 13-size convolution kernels. Figure 9 shows the error comparison before and after the algorithm optimization.

It can be seen from Figure 9 that, by comparing the errors before and after optimization with a genetic algorithm, it can be found that the optimized NN forecasting model is better than that before optimization, and the optimized NN can achieve the data fitting effect faster.

Predicting the mental health of college students is a complex and systematic process. Because the process by which each specific factor performs its function is invisible and intangible and because the influence on the outcome may be nonlinear, a method that can reflect the corresponding relationship between the factors that affect the psychological state and the outcome is required to develop the prediction model. The ability of the optimized NN to fit data is clearly improved without changing the original network structure and network parameters. The reason for this is that the genetic algorithm uses the fitness function to determine the optimal weights and thresholds and then passes those weights and thresholds to NN training to replace the random weights and thresholds generated by Matlab in each training. This severely limits the ability to adjust the weight threshold on one's own. The number of iterative steps in the NN is significantly reduced after optimization, and the preset goal can be reached much faster. Experiments show that using a genetic algorithm improves the initial weights and thresholds of CNN, allowing it to fit the data better.

The ability of fuzzy clustering analysis and prediction of optimized mental health data is obviously improved because CNN finds out the optimal weights and thresholds through fitness function and then gives the weights and thresholds to neural network training to replace the initial weights and thresholds randomly generated by Matlab in each training, which greatly reduces the ability of self-adjustment of weights and thresholds. By changing the parameters of the NN, the calculation of the final result of the prediction system is simple and flexible, and the prediction efficiency and accuracy of the network model are greatly improved. This provides a good reference method for the study of university students' psychological health to a great extent.

5. Conclusions

The significance of psychological health among university students is self-evident. It has a huge impact on university students, schools, society, and the country as a whole. Nowadays, the pace of university students' studies and lives is quickening, and social influence is growing, as well as psychological pressure on students. In terms of psychology, university students experience a variety of negative reactions and maladjustment. Some of them are downright dangerous. Suspension from school, dropping out, and even wounding and suicide as a result of mental illness have all increased in recent years. Psychological factors are the primary cause of psychological illnesses. Psychological issues have a significant impact on university students' development. As a result, universities have made it one of their top priorities to prioritise psychological health education for university students. The psychological well-being of university students has recently become a hot topic. The ability of fuzzy clustering analysis and prediction of optimized mental health data is clearly improved because CNN finds the optimal weights and thresholds through fitness function and then gives the weights and thresholds to neural network training to replace the initial weights and thresholds randomly generated by Matlab in each training, greatly reducing the ability of weights and thresholds self-adjustment. As a result, this paper builds a forecasting model of university students' psychological disorders based on CNN. The results show that the improved NN overcomes the drawbacks of the current mental disorder forecasting model, allowing university students to know their psychological health status in real time. It is a high-precision, high-efficiency model for predicting psychological disorders with a wide range of applications. We can predict students who may have psychological problems in advance using this NN psychological forecasting model, so that appropriate attention or measures can be provided on time, avoiding the enlargement or aggravation of students' psychological problems and ensuring the positive and stable development of schools and students.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Copyright Protection of Literary Works Based on Data Mining Algorithms

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In order to improve the copyright protection effect of literary works and improve the healthy dissemination of digitized literary works, this paper combines data mining technology to conduct research on the copyright protection of literary works and constructs a literary copyright protection system. In digital literary works, watermarking algorithms can be used to watermark the characteristics of literary works to obtain digital literary works that have been watermarked. After that, this paper can combine data mining algorithms to perform text feature recognition and feature classification and improve the copyright protection effect of literary works. The experimental research results verify that the effect of the copyright protection system of literary works based on data mining algorithms is very good.

1. Introduction

The rapid development of computer storage technology and network technology has brought massive amounts of information to people. This information usually takes images, videos, audios, animations [1], and texts as the main manifestations, among which texts have the widest range of dissemination and the highest frequency of use. The massive dissemination of information brings convenience to people's work and life, but it also has shortcomings, such as many copyright disputes and illegal copying problems, which urgently needs author identification methods that can resolve copyright disputes. Through research, it is found that texts written by different authors or authors have greater style differences, and different texts written by the same author have the same writing techniques, usual sentence structure, vocabulary, etc. [2]. The author recognition method first extracts and counts the features of a large number of texts written by different authors and trains the classifier. Then, for the controversial text, it uses effective feature extraction methods to obtain statistical vectors and input them into the trained classifier. Finally, it outputs specific classification categories or specific authors. The method of text author recognition can assist in resolving copyright disputes of disputed works (especially disputed works of well-known authors), combating piracy, and maintaining integrity. The key part of the text author recognition method is training and building a classifier [3].

Classification is a typical machine learning method with teachers, and it is also an important research topic in the field of data mining. The classification function or classifier is obtained by continuously learning training data. When classification is needed, the test data can use the obtained function or classifier to output a given category. How to choose a suitable classification model in the application is an important issue. Text classification technology can be widely used in fields such as natural language processing and understanding, information management, data evaluation, and information filtering. The more common text classification methods include support vector machine, K-nearest neighbor method, Bayesian classification, neural network, and decision tree classification. Support vector machine is mainly used in pattern recognition and other fields. It is a pattern recognition method based on statistical learning theory. Its characteristic is that it can maximize the geometric edge area and minimize the empirical error at the same time. According to the situation of the known samples, the nearest neighbor algorithm can determine whether the new sample and the known sample are in the same category. The nearest neighbor algorithm has many developments and improvements, but the general idea is to store all or part of the training samples first and then calculate the distance between the test sample and the training sample through the similar function and finally determine the type of the test sample. The nearest neighbor algorithm can quickly achieve classification, especially in the field of statistical-based pattern recognition. The principle of the neural network is to simulate the structure of the human brain and treat the sample as a connected input/output unit. The training sample learns by adjusting the unit value.

Based on this, this paper combines data mining technology to conduct research on the copyright protection of literary works, constructs a literary copyright protection system, and improves the copyright protection effect of modern digital literary works.

2. Related Work

Literature [4] proposed Triangle Similarity Quadruple (TSQ) and Tetrahedral Volume Ratio (TVR). The TSQ algorithm constructs the Macro Embedding Primitive (MEP) and selects the ratio of the side length of the triangle or the ratio of the base to the height in the MEP as the watermark embedding primitive: the TvR algorithm selects the four sides after constructing the tetrahedral sequence. The volume ratio between the volumes is used as the watermark embedding primitive. Literature [5] calculates the distance from each vertex of the model to the center of the vertex field and the distance from the center of the model and embeds the watermark by modifying the ratio between the two. This algorithm is a non-blind watermarking algorithm, which can resist similar transformation, noise, simplification, and their joint attacks. However, the transparency of the watermark is insufficient.

Literature [6] proposed two digital watermarking algorithms based on local distance: Vertex Flood Algorithm (VFA) and Triangle Flood Algorithm (TFA). The VFA algorithm divides the vertex set according to the distance from the vertex of the model to the center of the selected triangle and embeds the watermark by modifying the distance from the vertex in each set to the center of the selected triangle; the TFA algorithm continuously selects the triangle and connects the adjacent triangles of the triangle, sorting into a triangle traversal sequence according to the distance from the non-shared vertex to the shared edge, and then modifying the height of each triangle in the traversal sequence to achieve the purpose of embedding the watermark. Literature [7] embeds the watermark by modifying the distance from the model vertex to the center of the model. As a global geometric feature, this distance can well reflect the shape of the 3D model and can maintain sufficient stability without changing the visual effect of the model. Therefore, the algorithm has better robustness against noise and simplification attacks; literature [8] improves the transparency of the watermark by controlling the intensity of local watermark embedding, and uses a weighting method to improve the simplification and reduction of the watermark during watermark extraction. Robustness of noise attacks: literature [9] embeds both robust and fragile watermarks in the 3D model by modifying this distance and uses the method of adding weights to improve the robustness of the algorithm when extracting the watermark. Literature [10] proposed a multiple digital watermarking algorithm. This algorithm uses the distance from the vertex to the center of the model to embed the watermark and at the same time introduces the affine invariant range and embeds the second watermark by modifying the vertex order of the triangle face. The complementary advantages of the two watermarks increase the types of algorithms against attacks. Literature [11] focuses on improving the transparency of watermarking. Literature [12] improves the method of controlling the embedding strength of local watermarks. Literature [13] uses the K-means clustering method to select a specific set of vertices according to the curvature of the vertices and uses genetic algorithms to embed the watermark.

Literature [14] proposed a digital watermarking algorithm based on Extended Gauss Image (EGI). The algorithm builds a set of triangle faces based on the normal vector of the triangle face and embeds the watermark by modifying the statistical feature of the mean value of the normal vector of each set. Literature [15] divides the vertices of the 3D model into 6 regions, and each region establishes an extended Gaussian image of the normal vector, which realizes the repeated embedding of watermark information in each region and optimizes the method of modifying the vertex coordinates. Literature [16] proposed a digital watermarking algorithm based on complex extended Gaussian image (Copmlex EGI), which establishes a complex weight for each partition and selects the partition with larger weight to embed the watermark, which effectively improves the robustness. Literature [17] uses the vertex neighborhood of each vertex to calculate an average vector and embeds the watermark by modifying the length of the average vector. The algorithm can handle polygonal mesh models with arbitrary topologies and has good robustness to affine transformations, but it cannot resist attacks such as mesh reconstruction and mesh simplification. Literature [18] uses the model center and principal component analysis method to transform the model into an affine invariant space and transforms the vertex coordinates into spherical coordinates and then constructs a histogram reflecting the value distribution of the radial component of the vertex according to the spherical coordinates. The histogram moderately changes the distribution of the radial component to embed the watermark. The algorithm can resist similar transformation and simplification attacks, but it cannot resist shearing attacks, and it has weak resistance to noise attacks. Literature [19] defines the distance from the vertex of the 3D model to the center of the model as the vertex norm and proposes a highly robust blind watermarking algorithm based on the statistical characteristics of the vertex norm. This algorithm establishes a histogram of all vertex norms, divides the histogram into several partitions according to the number of watermarks, and embeds the watermark by slightly changing the mean or variance of the vertex norm of each partition. This algorithm combines the stability of both the global geometric features and statistical features of the 3D model and has achieved good robustness against various common attacks. However, the algorithm depends on the center position of the model, so it cannot resist shearing attacks. And there are also shortcomings in transparency.

3. Literary Works Watermarking Algorithm Based on Text Data Mining

By analyzing the characteristics of common BIM model format DXF files, this paper combines the existing two-dimensional vector graphics digital watermarking algorithm to propose a digital watermarking algorithm for data copyright protection based on the BIM model. This paper selects the vertex coordinates of the multiface mesh of the entity of the BIM model data to embed the watermark. In order to solve the problem that the vertex coordinates in the BIM model have more identical values and less effective carriers used to embed the watermark in practical applications, random noise is added to the original coordinate data within the error tolerance to increase the embedding capacity of the watermark. In order to enhance the ability to resist pruning attacks, the watermark information needs to be embedded as evenly as possible in the X and Y coordinates of all multiface mesh vertices of the BIM model data. In order to maintain the synchronization relationship between data and watermark and realize blind watermark detection, the idea of coordinate mapping is adopted. At the same time, the security of the watermark is improved by Logistic scrambling of the watermark image. In this algorithm, firstly, it extracts the vertex coordinates of all the multiface meshes in the data to construct a vertex set and obtains the high-level part of the coordinate data. After that, it establishes a mapping relationship with the watermark through a one-way mapping function to use the low-order part of the coordinate value as the embedding carrier of the watermark and embeds the watermark into the vertex coordinate position using the quantization modulation method. Moreover, it selects the initial value of chaotic transformation as the key for watermark extraction. When the watermark is extracted, no original data is needed, and blind detection is realized. The embedding process of the watermark is shown in Figure 1.

Logistic mapping, also known as insect mouth model, is a typical chaotic sequence in chaos theory, and its equation form is formula (1). Chaos phenomenon is a random-like process that appears in a deterministic system. The process is bounded, non-convergent, and sensitive to initial values. The use of chaotic sequences to encrypt the watermark not only is simple and easy to use, but also has no periodicity and is difficult to crack, which can improve the security of the watermark. For an image of $M \times N$ size, a one-dimensional chaotic encryption sequence w is obtained after $M \times N$ iterations.

$$L_{i+1} = \mu L_i (1 - L_i), \ (i = 0, 1, 2, \ldots, m \times n). \tag{1}$$

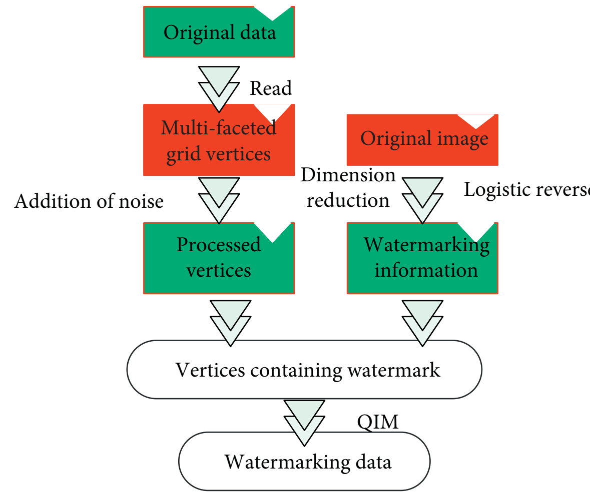


FIGURE 1: Flow chart of watermark embedding.

When the condition $0 < L_i < 1, 3.5699456 \ldots < \mu \le 4$ is satisfied, the Logistic mapping works in a chaotic state. In particular, when μ is close to 4, the iteratively generated value is a pseudo-random distribution state. This paper uses the Logistic chaotic map to encrypt an image of 32×64 size and then reduces the dimensionality of the generated binary watermark image to obtain a one-dimensional sequence w with a length of $S = w_m \times w_n$. The initial value $L_0 = 0.98$ of the chaotic transformation is selected for many trials. Figure 2(a) is the original image used in the experiment, Figure 2(b) is the chaotic image after scrambling, and Figure 2(c) is the decrypted image after inverse scrambling [20].

Due to the large number of coordinate repeated values in the BIM model, there are fewer effective carriers for embedding the watermark. To solve this problem, this paper adds random noise to the original coordinate data within the error tolerance to increase the embedding capacity of the watermark. The repeated coordinate values in the vertices set of the polyhedral mesh of the original data are subjected to the noise adding operation shown in formula (2) to obtain the processed vertex set V_e [21].

$$\begin{cases} x_e = x + \text{rand} \times Q \\ y_e = y + \text{rand} \times Q \end{cases}. \tag{2}$$

Here, (x_e, y_e) represents the vertex coordinates of the polyhedral mesh after adding noise, (x, y) is the vertex coordinates of the original data, rand is a random function that generates a random number within (0,1), and Q is the allowable range of error.

This algorithm embeds the watermark with the multifaceted mesh vertices of the BIM model data entity as the object. The vertices of the multifaceted mesh of the BIM model data are set V_K, denoted as $V_K = \{V_i\}, V_i = (x_i, y_i), i \in \{0, 1, 2, \ldots, K-1\}$. Among them, V_i represents the vertex of each polyhedral mesh, (x_i, y_i) is the X, Y coordinate value of the vertex, and K represents the number of vertices of the polyhedral mesh.

(a) (b) (c)

Figure 2: Original watermark.

The specific process of watermark embedding is as follows:

Step 1. The algorithm reads the BIM model data, extracts all the multiface mesh vertices in the model object entity, and constructs the multiface mesh vertex set V_K.

Step 2. The algorithm adds noise to the two coordinate values (x_i, y_i) of each vertex V_i in the set V_K and at the same time enlarges it by 10 times, which is denoted as V_i' , $V_i' = (x_i', y_i')$. Among them, V_i' represents each polyhedral mesh vertex after noise processing, and (x_i', y_i') is the two coordinate values after noise is added to the vertex.

Step 3. The algorithm selects the embedded bit x_w of the watermark according to the data accuracy requirements, and the selection method is as in formula (3). Then, the algorithm gradually modifies the vertex coordinates of the multiface mesh according to the mapping relationship between the high part of the data and the watermark bit $w(x_w)$;

$$x_w = \text{floor}\left(\text{mod}\left(\frac{x_i'}{p, S}\right) + 1.\right. \quad (3)$$

Here, floor represents rounding down, the mod function is the modulo operation and returns the remainder after dividing x_i'/p by S, p is the difference between the magnification and the most significant digit after the decimal point, and S represents the length of the watermark, and $p = 1000$ is selected in this paper.

Step 4. The algorithm uses quantization modulation technology to embed the watermark into the processed coordinate value x_i' and calculate the embedded watermark data x_i^w, where the quantization amplitude is R. There are two cases according to the value of the embedded watermark, as follows [22]:

$$\begin{aligned} x_i^w &= x_i' - \frac{R}{2}, \text{ if } w(x_w) = 0 \text{ and } \text{mod}(x_i', R) \geq \frac{R}{2}, \\ x_i^w &= x_i' + \frac{R}{2}, \text{ if } w(x_w) = 1 \text{ and } \text{mod}(x_i', R) < \frac{R}{2}. \end{aligned} \quad (4)$$

In the same way, according to the different embedded watermarks and the QIM method, the watermark is embedded in the y_i' coordinate of the vertex V_i' of the multifaceted mesh.

Step 5. The algorithm reduces the coordinate value (x_i^w, y_i^w) in V_i^w after the watermark is embedded by 10^t times, and merges the unmodified data with it to generate the watermarked BIM model data.

The extraction of watermark is the reverse process of watermark embedding (Figure 3). The specific steps to extract the watermark are as follows:

Step 1. The algorithm reads the BIM model data to be detected, extracts all the vertices of the multifaceted mesh that can be watermarked, and magnifies the vertex coordinates by 10^t times, where the selection of magnification index t is the same as the value of t when the watermark is embedded.

Step 2. According to the mapping relationship established by the one-way mapping function and the watermark, the algorithm finds the position x_w of the watermark.

Step 3. The algorithm performs QIM operation based on the quantized value R when the watermark is embedded, and extracts the value of the watermark bit $w'(x_w)$ by formula (6).

$$\begin{cases} w'(x_w) = w(x_w) - 1, \text{mod}(x_i^w, R) < \dfrac{R}{2} \\ w'(x_w) = w(x_w) + 1, \text{mod}(x_i^w, R) \geq \dfrac{R}{2} \end{cases}. \quad (5)$$

Step 4. In this algorithm, the same watermark is embedded multiple times, and the value of the watermark bit $w'(x_w)$ can be used to determine the value of the extracted watermark information w'':

$$\begin{cases} w'' = 1, w'(x_w) < 1 \\ w'' = 0, w'(x_w) \geq 1 \end{cases}. \quad (6)$$

This shows that when the value of the extracted watermark bit is less than 1, the value of the watermark information is 1; otherwise it is 0.

Step 5. The algorithm performs dimension increase processing on the obtained one-dimensional watermark information w' and inversely scrambles to obtain the watermark image W'.

Step 6. Finally, the watermark similarity is evaluated by calculating the normalized correlation coefficient

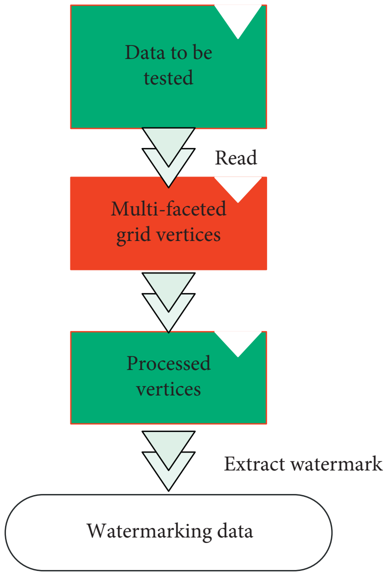


Figure 3: Flow chart of watermark detection.

between the original watermark and the extracted watermark. The calculation formula is as follows:

$$NC = \frac{\sum_{M}^{m=1}\sum_{N}^{n=1}[W'(m,n)\times W(m,n)]}{\sqrt{\sum_{M}^{m=1}\sum_{N}^{n=1}[W'(m,n)]^2}\times\sqrt{\sum_{M}^{m=1}\sum_{N}^{n=1}[W(m,n)]^2}}. \quad (7)$$

Here, NC is a measure of similarity. The greater the value, the greater the similarity. The size of the watermark image is $\times N$, $W(m,n)$ represents the original watermark information, and $W'(m,n)$ is the extracted watermark information.

The BIM model data is a digital expression of the physical function characteristics of the engineering project facility. Based on 3D digital technology, it integrates engineering data model data of various related information of construction projects. The diversity of BIM professional software has led to the diversification of data formats. The format of BIM model data is very important for the selection of hidden domains. The research and development of existing application systems are all based on geometric data models, and data exchange is mainly carried out through graphics information exchange standards such as IGES, DXF, and DWG.

DXF data model is often used for information exchange between AutoCAD and other software. It is mainly composed of graphic objects and non-graphic objects and also contains limited attribute information, which is convenient to operate. For BIM model data in DXF format, the vertices of the multifaceted mesh are an important feature position of the model data. However, the coordinates of the vertices of the multiface mesh in the BIM model data have many repeated values, and there are fewer effective carriers for embedding watermarks. In order to solve this problem, random noise is added to the frequency domain amplitude coefficient after transformation of the original coordinate data within the error tolerance range to increase the watermark embedding capacity. As shown in Figure 4, W1 is the watermark image extracted without any processing on the original data, and the image has serious noise, and W2 is the watermark extracted after the noise preprocessing, and the watermark image is clearly visible.

The algorithm proposed in this paper includes watermark embedding part and watermark extraction part. First, this paper selects the multiface mesh elements in the BIM model data as the unit and constructs a complex number sequence with all the multiface mesh vertices as characteristic points. Moreover, this paper uses the DFT transform to obtain the amplitude coefficient as the embedding carrier of the watermark, uses the QIM method to embed the watermark on the amplitude coefficient of the DFT frequency domain, and then performs IDFT transform to obtain the watermarked BIM model data. When it is attacked, the watermark is extracted, the watermark is extracted through the voting principle, and the correlation method is used to detect. At this time, the original data is not needed, and blind detection is realized. In order to enhance the ability to resist the attack of deleting entities, the watermark information is evenly embedded in the X and Y coordinate transformation coefficients of all multiface mesh vertices in the BIM model data as much as possible. In order to reduce the excessive influence on the original data, the amplitude value is enlarged. In order to maintain the synchronization relationship between data and watermark and realize blind watermark detection, the idea of coordinate mapping is adopted. According to the nature of DFT transformation, in order to avoid the large error caused by the translation attack on the data, the watermark is not embedded on the first transformation coefficient amplitude value of the set of vertices of the multiface mesh. To ensure the security of the watermark, Logistic chaotic mapping is used to scramble the original watermark image. The flowchart of the algorithm is shown in Figure 5.

First, the BIM model data in the space domain needs to be DFT-transformed to the frequency domain. The specific process of the transformation is as follows:

Step 1. $V_d = \{v_j\}, v_j = (x_j, y_j)$ represents the set of all polyhedral mesh vertices in the original BIM model data, where $j = 1, 2, \ldots, N$, v_j is the coordinates of the polyhedral mesh vertices, (x_j, y_j) is the X, Y coordinate value of the vertices, and N is the number of polyhedral mesh vertices. Using multiface mesh elements as the unit, the complex number sequence $\{a_j\}$ is generated as follows:

$$a_j = x_j + iy_j, j \in \{1, 2, 3, \ldots, N\}. \quad (8)$$

Step 2. For the N point sequence $\{a_j\}$, its DFT transformation is shown as follows:

$$A_l = \sum_{j=1}^{N} a_j\left(e^{-2\pi i/N}\right)^{jl} j, l \in \{1, 2, \ldots, N\}. \quad (9)$$

Here, A_l represents the data after DFT transformation. a_j in the formula can be a complex value. In practice, a_j is a real

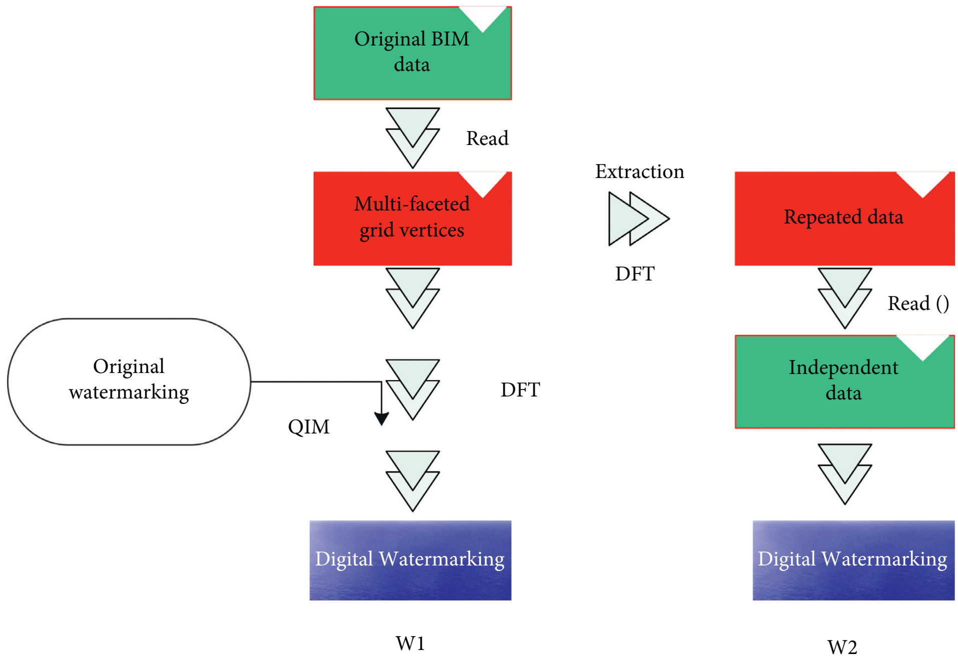


Figure 4: Preprocessing of raw data.

value, that is, the imaginary part is 0. At this time, the formula can be expanded to

$$A_l = \sum_{j=1}^{N} a_j\left(\cos\left(2\pi l \frac{j}{N}\right) - i\times \sin\left(\pi l \frac{j}{N}\right)\right), l \in \{1, 2, \ldots, N\}. \quad (10)$$

The sequence coefficient has two values, the amplitude coefficient $|A_l|$ and the phase coefficient $\angle A_l$, as shown in formula (11). The set of amplitude coefficients is denoted as $\{|A_l|\}$, and the set of phase coefficients is $\{\angle A_l\}$.

$$\begin{cases} |A_l| = \sum_{j=1}^{N} a_j \cos 2\pi l \frac{j}{N}, l \in \{1, 2, \ldots, N\} \\ \angle A_l = \sum_{j=1}^{N} -a_j \sin \pi l \frac{j}{N}, l \in \{1, 2, \ldots, N\} \end{cases}. \quad (11)$$

The specific steps of the watermark generation and embedding algorithm are as follows:

(1) The generation of watermark information. The algorithm reads an image with a size of $M \times M\,(M \geq 2)$ pixels as the original watermark image. In order to improve the security of the watermark, the original watermark is scrambled by Logistic mapping, and the dimensionality of the scrambled binary matrix is reduced to obtain a one-dimensional binary sequence W, where the sequence expression formula is $W = \{w_m = 0, 1 | m = 0, 1, \ldots, P-1\}$, and P represents the length of the watermark.

(2) The algorithm reads the BIM data, the amplitude coefficient $\{|A_i|\}$ obtained by DFT transformation of $\{a_j\}$ is expanded by 10^7, and the noise is added.

(3) The algorithm uses the QIM method to embed the watermark into the amplified amplitude coefficient and obtain the embedded watermark amplitude coefficient $|A_l|$ through the following equation:

$$\begin{cases} |A_l'| = |A_l| - \frac{R}{2}, w_m = 0 \text{ And} \bmod (A_l, R) \geq \frac{R}{2} \\ |A_l'| = |A_l|, w_m = 0 \text{ And} \bmod (A_l, R) < \frac{R}{2} \\ |A_l| = |A_l| + \frac{R}{2}, w_m = 1 \text{And} \bmod (A_l, R) < \frac{R}{2} \\ |A_l'| = |A_l|, w_m = 1 \text{ And} \bmod (A_l, R) \geq \frac{R}{2} \end{cases}. \quad (12)$$

(4) The algorithm scales the obtained $|A_l|$ to restore it to the original data size, and the reduction factor is equal to the enlargement factor.

(5) The algorithm combines the obtained embedded watermark amplitude value with the unmodified phase coefficient to generate a new coefficient $\{A_l\}$, and then IDFT transforms it to obtain the complex number sequence $\{a_l\}$ after embedding the watermark.

(6) The algorithm modifies the vertices of the multifaceted mesh according to $\{a_l'\}$ and obtains the set of multifaceted vertices V_d', $V_d' = \{v_j' = (x_j' + y_j')\}$, $j \in \{1, 2, \ldots, N\}$, after the watermark is embedded, so as to obtain the BIM data after the watermark is embedded.

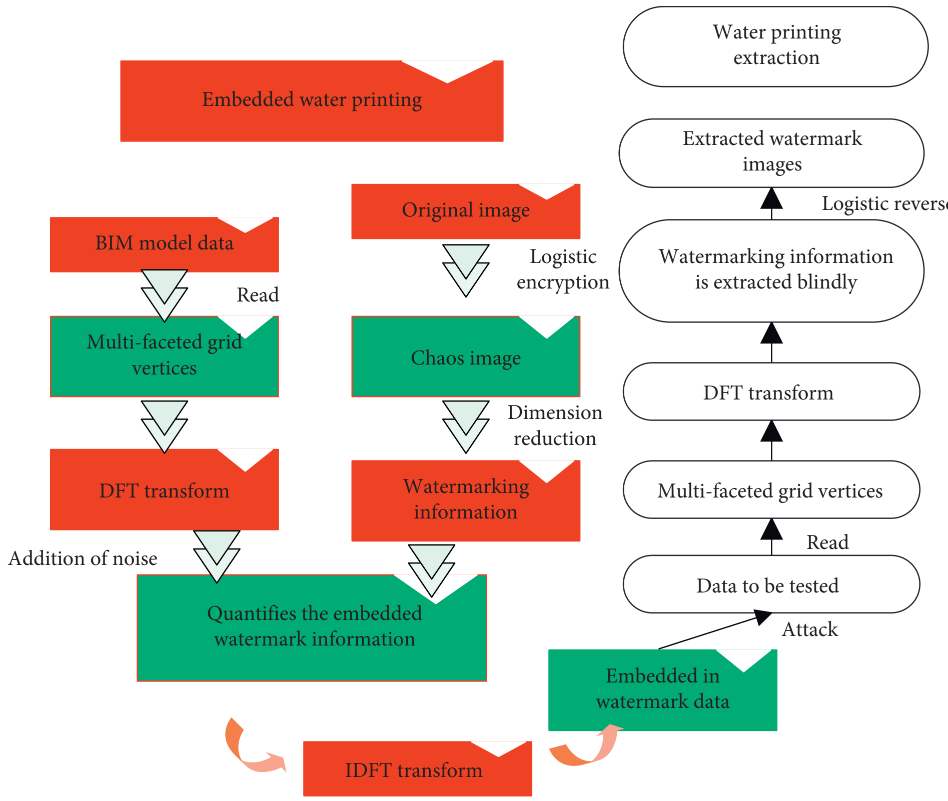


Figure 5: Watermark embedding and extraction framework.

The essence of watermark extraction is the reverse process of watermark embedding. When the data owner finds suspicious BIM model data, the algorithm extracts the watermark according to the following steps:

(1) The algorithm reads the vertices of the multifaceted mesh of the BIM data to be tested, forms a set V_d', and generates a complex number sequence $\{a_j'\}$ according to formula (8).

(2) The algorithm performs DFT transformation on $\{a_j'\}$ to obtain the amplitude coefficient of the coefficient $\{|A_j|\}$.

(3) The algorithm uses the parameters consistent with the embedding process and uses the QIM method to extract the value of suspicious $\{w_m'\}$. The extraction process is as follows:

$$\begin{cases} w_m' = w_m - 1, \mathrm{mod}\left(\left|A_l'\right|, R\right) < \dfrac{R}{2} \\ w_m' = w_m + 1, \mathrm{mod}\left(\left|A_l'\right|, R\right) \geq \dfrac{R}{2} \end{cases}. \tag{13}$$

(4) For the extracted one-dimensional watermark $W' = \{w_m' = 0, 1 | m = 0, 1, \ldots, P-1\}$, the algorithm performs dimensional increase processing and Logistic inverse scrambling to extract the watermark image.

(5) The algorithm uses equation (14) to calculate the normalized correlation coefficient between the extracted watermark image and the original watermark image to measure the robustness. The larger the value of NC, the more similar the two and the better the robustness.

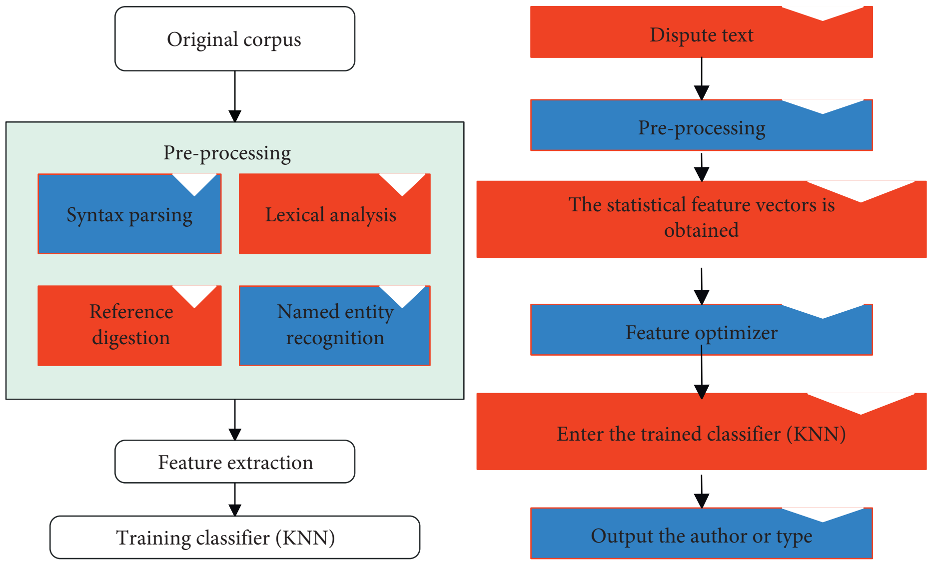
$$NC = \frac{\sum_{m=1}^{M}\sum_{m=1}^{M} XNOR\left(W(m1, m2), W'(m1, m2)\right)}{M \times M}. \tag{14}$$

Here, $M \times M$ is the size of the watermark image, XNOR is the exclusive OR operation, $W(m1, m2)$ is the original watermark information, and $W'(m1, m2)$ is the extracted watermark information. Among them, the closer NC is to 1, the more robust the algorithm is.

4. Literary Works Protection Based on Data Mining Algorithm

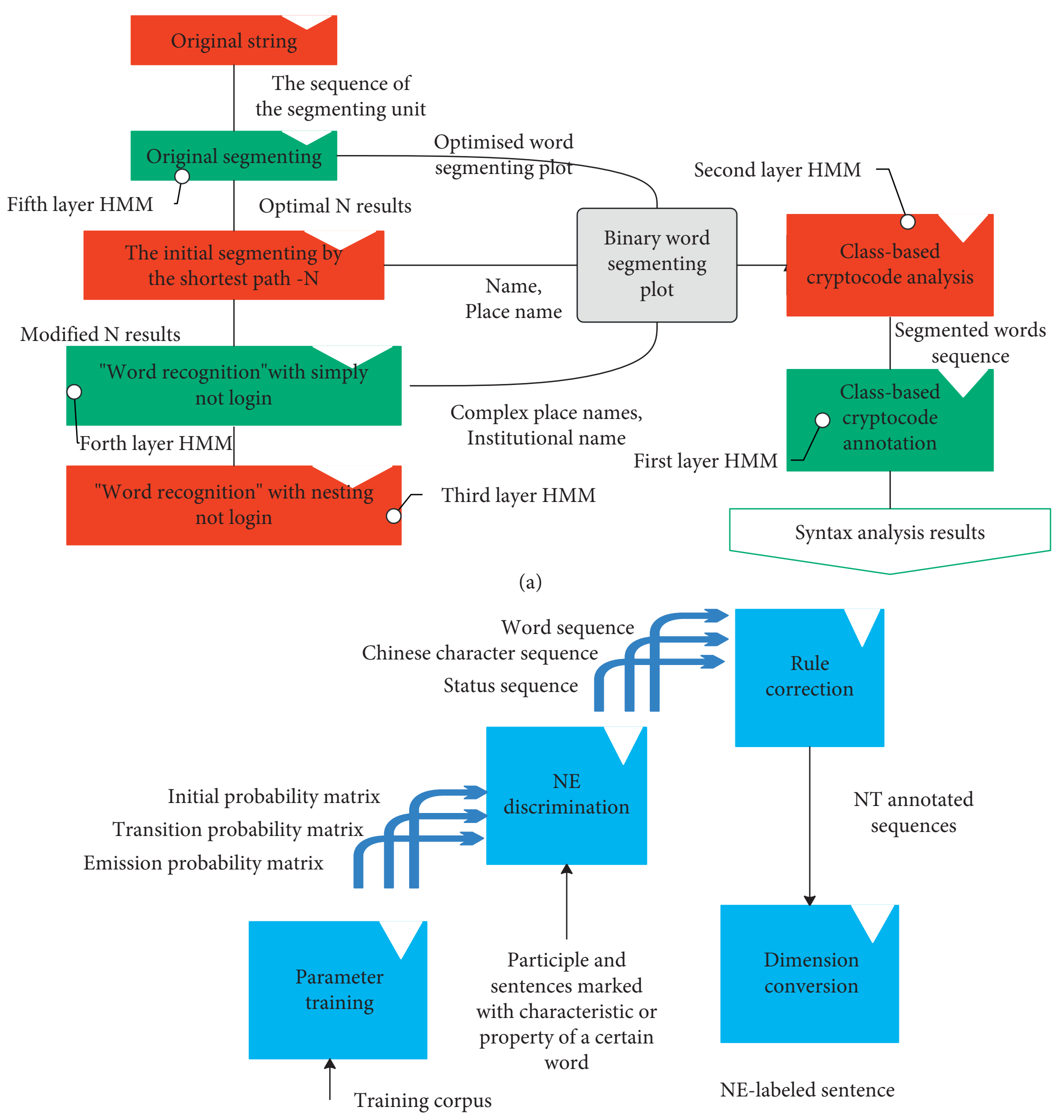
In digitized literary works, we can use watermarking algorithm to watermark the characteristics of literary works to obtain digital literary works that have been watermarked. After that, we can combine data mining algorithms to perform text feature recognition and feature classification to improve the copyright protection effect of literary works.

Author recognition method mainly includes two modules: training module and classification module. The functions of the training module mainly include the process of preprocessing the original corpus, extracting key features of the text, and training to obtain the classifier. The function of the dispute text classification module is to preprocess the



(a) (b)

Figure 6: Model function module structure. (a) Training module diagram. (b) Classification module diagram.



(b)

Figure 7: The watermark feature extraction function module of literary works. (a) Word segmentation system structure. (b) Structure diagram of named entity module.

Table 1: The effect of text data mining algorithm in watermarking algorithm feature recognition.

Number	Feature recognition
1	95.183
2	93.852
3	93.653
4	95.726
5	95.049
6	91.902
7	94.023
8	94.907
9	96.732
10	95.449
11	95.724
12	95.523
13	96.018
14	94.768
15	95.937
16	94.456
17	95.630
18	92.033
19	92.519
20	92.548
21	92.969
22	93.626
23	93.265
24	92.590
25	96.462
26	95.158
27	91.251
28	93.333
29	91.036
30	96.041
31	91.626
32	92.056
33	95.413
34	93.730

Table 2: Evaluation of copyright protection effect.

Number	Copyright protection
1	90.335
2	87.370
3	79.406
4	90.760
5	83.105
6	89.303
7	78.790
8	78.987
9	89.762
10	88.496
11	80.300
12	89.035
13	80.199
14	84.078
15	87.036
16	86.804
17	83.225
18	78.005
19	78.938
20	89.517
21	84.643
22	86.895
23	84.018
24	78.786
25	83.654
26	80.734
27	84.245
28	87.999
29	88.636
30	84.305
31	83.862
32	83.266
33	79.180
34	86.801

dispute text, extract the statistical feature vector from the dispute text, and then input it into the trained classifier, and finally output the author category from the classifier. The methods used in the first two stages of these two modules are exactly the same. The main function of the training module is to build a training classifier. If it is a controversial work, then extract the key statistical features from it and input it into the trained classifier, and finally judge the author's category based on the similarity value. The flowcharts of the training module and the classification module are shown in Figures 6(a) and 6(b), respectively.

The corpus must first undergo text normalization processing, and after it is expressed in a form that can be processed by the computer, the normalized text segmentation is processed. The system structure is shown in Figure 7(a). The named entity refers to the actual content of the entity expressed in the Chinese text sentence, such as unit name, person, geographic name, organization name, etc. One of the basic tasks in natural language processing technology is named entity recognition, which plays an important role in word segmentation, syntactic analysis, and automatic translation with the help of machines and other technologies. At present, the lexical analysis technology researched by the Chinese Academy of Sciences and Harbin Institute of Technology has a module for Chinese text sentence named entity recognition. The principle of this module is shown in Figure 7(b).

After combining the watermarking algorithm to obtain the above model, this paper conducts experimental verification on the model. First, the effect of the text data mining algorithm in the feature recognition of the watermarking algorithm is verified, and the results shown in Table 1 are obtained.

The above verifies that the text data mining algorithm has a very good effect in the feature recognition of the watermark algorithm. On this basis, the copyright protection effect is evaluated. This part is carried out by the expert evaluation method, and the results are shown in Table 2.

The above research has verified that the copyright protection effect of literary works based on data mining algorithms is very good.

5. Conclusion

While the digitization of literary works brings a new production and lifestyle to people, its own characteristics have brought a copyright crisis to itself. When digital products exist in digital form, they can be easily edited, modified, and stored through computers or other digital equipment. At the same time, it can also carry out low-cost and lossless copying and transmission through various forms of storage media, computer networks, or other data transmission methods. The advantages of these original digital literary works make it very easy to illegally occupy, copy, edit, and disseminate unauthorized products that infringe on the owner's copyright. This paper combines data mining technology to study the copyright protection of literary works, constructs a literary copyright protection system, and improves the copyright protection effect of modern digital literary works. The experimental research results verify that the effect of the copyright protection system of literary works based on data mining algorithms is very good.

Data Availability

The labeled dataset used to support the findings of this study is available from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

Acknowledgments

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Research Article

Evaluation and Optimization of College English Teaching Effect Based on Improved Support Vector Machine Algorithm

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Improved SVM algorithm improves the efficiency of College English teaching effect evaluation and meets the requirements of College English teaching evaluation. Based on the relevant theories, this paper constructs the evaluation index system with teachers and students as the main body and takes the questionnaire survey results as the input samples of the LSSVM algorithm. Compared with the evaluation accuracy of an optimized BP neural network and the category weighted gray target decision-making method, the results show that the evaluation accuracy of optimized LSSVM algorithm is 96.26%. Taking SIT as an example, this paper uses the optimized LSSVM algorithm to evaluate its teaching effect and obtains that teachers' literature and teaching contents are important factors to improve the effect of English teaching. Therefore, this paper introduces the intelligent voice system to optimize the English teaching design of SIT. The teaching design is optimized from the dimensions of teaching objectives, learning situation, teaching content, teaching media and curriculum materials, and teaching procedures.

1. Introduction

Teaching effect evaluation has become a hot issue in the field of education at home and abroad. Teaching effect is the core of school survival and development. Teaching evaluation is a very important and indispensable part of the teaching process and an important means to test the teaching effect. Traditional teaching evaluation methods only focus on students' learning effect, which is not conducive to the reform of English teaching methods and contents.

English teaching effect evaluation refers to the evaluation of teachers' teaching effect from the aspects of teaching content, subject organization, teaching achievement, and learning interest. Through the evaluation, the direction of curriculum optimization can be put forward. Eleni et al. (2012) believe that teaching motivation and teaching satisfaction are the main factors of curriculum teaching effect and put forward effective evaluation methods for teaching motivation, such as the experimental method, questionnaire method, and text analysis method [1]. The traditional questionnaire survey and observation evaluation cannot objectively evaluate the classroom quality for a long time and cannot obtain clear evaluation results. In this case, Li et al. (2019) propose an intelligent school teacher quality evaluation platform. By considering the sensor information, flow information, and power information of mobile devices in the teaching process, the teacher quality evaluation score is given through the neural network training classification model [2]. Nalla (2019) proposes an evidence-based teaching strategy evaluation framework [3]. Leong et al. (2012) discuss the method of analyzing text mining of short message service (SMS) in teaching evaluation, and analyze and classify the information [4]. Ahmad (2018) analyzes how to the improve students' response rate to teaching curriculum evaluation through the survey results. The survey results show that the effective communication of teachers can effectively improve students' participation in the evaluation of teaching curriculum quality [5]. Cadez et al. (2017) analyze the relationship between learning style and academic achievement of accounting students through teacher evaluation [6]. Bi (2018) studies the teaching evaluation grade and uses the evaluation based on statistical process control theory and standard deviation diagram to evaluate the school teaching grade [7].

In the selection of evaluation methods, the emotion classification model is widely used. Mullen and Collier (2004) first analyze the syntax between texts and then further analyze the emotion of the text based on the SVM algorithm [8]. Moraes et al. (2013) integrate the machine learning algorithm and deep learning technology into teaching effect evaluation, compare the classification effect of the support vector machine algorithm with that of the artificial neural network algorithm, and prove that the classification effect of ANN is equivalent to that of SVM [9]. Besides, Fuzzy mathematics theory, analytic hierarchy process, and BP neural network are also commonly used in the evaluation of CETE. Kennedy and Eberhart (1997) proposed an evolutionary algorithm to solve discrete problems based on the study of bird foraging behavior. Compared with the genetic algorithm, it has faster convergence speed in solving multiuser detection problems [10].

Sun (2020) et al. have developed an online English teaching assistant system, which uses the decision tree algorithm and a neural network to generate an English teaching evaluation model based on decision tree technology and studies the potential relationship between the evaluation results and various factors [11]. However, optimizing the evaluation model of college teaching quality based on the BP neural network will ignore the factors of teaching quality, resulting in the low accuracy of CETE evaluation. Krohling and de Souza (2012) define the positive and negative target distance from each scheme to the positive and negative ideal scheme, and sort the schemes according to the comprehensive target distance of each scheme [12]. The teaching evaluation method based on category weighted gray target decision making has low evaluation efficiency due to the complex calculation process. In the application of the intelligent system to curriculum teaching, the student model of the intelligent teaching system based on the Bayesian network established by Lan (2020) can not only objectively evaluate students' cognitive ability but also infer students' next learning behavior [13]. Myers (2021) uses the intelligent teaching system to automatically detect students' emotional state and guide students into a positive learning state [14]. Ramadan and Vasilakos (2017) collected shallow brain activity signals, extracted specific brain waves according to specific frequencies, and evaluated students' attention, emotion, and cognitive load [15].

The existing CETE research mainly focuses on the selection of the evaluation model and the improvement of model accuracy, and there is less research on practical application and optimization means. This paper not only optimizes the evaluation model but also innovatively introduces information technology means such as the intelligent voice system to improve the level of College English teaching. Based on the past research, this paper finds that mathematical algorithms are widely used in the evaluation of CETE, but most of them only use one method, and the optimization of the algorithm needs to be further improved. In this paper, the SVM algorithm is used as the evaluation method of CETE, and the PSO algorithm is used to optimize the SVM algorithm.

This paper constructs the evaluation index system from the perspectives of teachers and students and fully considers students' interests and teachers' feelings. By comparative analysis, the algorithm with the highest accuracy is selected as the evaluation method of this paper, and the selected evaluation method is applied to practice to obtain the most important influencing factors. The intelligent voice system is introduced to optimize College English teaching curriculum design, the improvement of teaching evaluation quality is fully considered, and curriculum design optimization is carried out while improving students' English learning achievements and considering students' interests and learning needs. In the evaluation process of this paper, the effect of College English teaching is divided into four levels: excellent, good, pass, and fail, and the optimized algorithm is used for empirical research. Firstly, this paper selects the Shanghai Institute of Technology for a case study to evaluate its College English teaching effect. Secondly, according to the evaluation results of each index and the overall evaluation results, the most important index in the process of curriculum optimization design is obtained. Finally, the intelligent speech system is introduced to formulate the optimization scheme and suggestions of College English teaching curriculum design.

2. Evaluation Model of College English Teaching Effect

2.1. Evaluation Index System of College English Teaching Effect. There are many theories for the evaluation system of College English teaching effect. Teachers and students are the two main bodies of the classroom, and they participate in the whole process of teaching. Therefore, starting from these two subjects, CETE can be evaluated more comprehensively. According to the relevant theories, an evaluation index system with teachers and students as the theme is constructed, as shown in Figure 1. The evaluation index system constructed in this paper can evaluate the teaching effect more comprehensively from the main perspective of students and teachers and from the different perspectives of participants in teaching activities. From the perspective of students, the evaluation index mainly comes from their feelings in class. Therefore, the evaluation indicators from the perspective of students mainly include course content, class atmosphere, teaching order, teaching skills, sense of responsibility, and interest. From the perspective of teachers, the evaluation indicators mainly come from the actual teaching effect and the number of courses. Therefore, the evaluation indicators from the perspective of teachers mainly include students' performance, correcting homework, the number of classes dismissed in advance, the number of classes transferred, and the number of classes suspended. The interpretation and definition of indicators are shown in Table 1.

Teachers' sense of responsibility and English achievement are important indicators to evaluate the effect of College English teaching. The evaluation index data of College English teaching effect are used as the input sample of the least squares support vector machine to realize the evaluation of College English teaching effect.

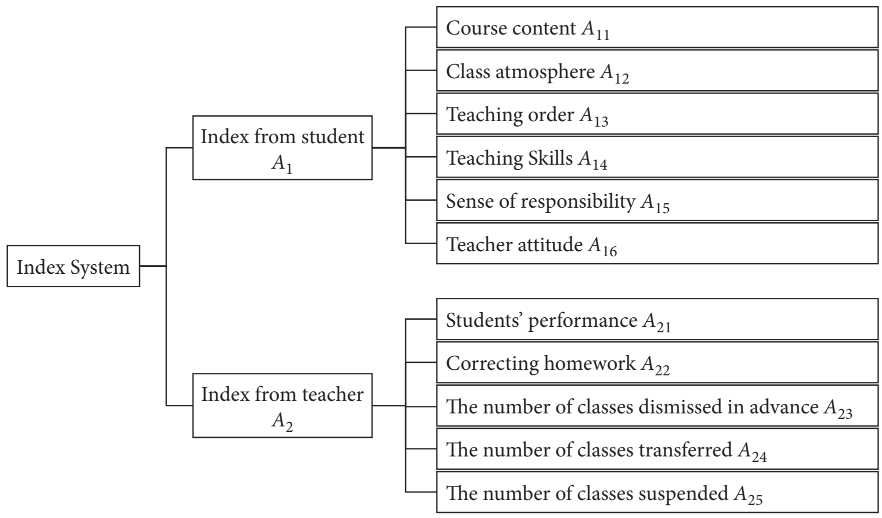

Figure 1: Evaluation index system of CETE.

Table 1: English teaching effect evaluation index.

	Index	Explanation
A_{11}	Course content	Reasonableness of English subject content
A_{12}	Class atmosphere	The quality of English topic atmosphere
A_{13}	Teaching order	The organization and hierarchy of lectures
A_{14}	Teaching skills	Teachers' teaching skills
A_{15}	Sense of responsibility	Teachers' sense of responsibility to students
A_{16}	Teacher attitude	The seriousness of teachers in correcting homework
A_{21}	Students' performance	Students' performance in class
A_{22}	Correcting homework	Accuracy of operation
A_{23}	The number of classes dismissed in advance	The teacher dismissed the class early for reasons other than the course
A_{24}	The number of classes transferred	Teachers change classes for reasons other than the course
A_{25}	The number of classes suspended	Teachers do not attend classes for reasons other than the course

2.2. Evaluation Principle of LSSVM. This paper uses the least squares support vector machine (LSSVM) method to evaluate English language teaching. LSSVM is one of the most widely used methods with good accuracy and precision in nonlinear signal processing. Compared with artificial neural networks, it can overcome the disadvantages of long training time, randomness of training results, and overlearning [16]. Compared with SVM, LSSVM transforms inequality constraints into equation constraints and quadratic programming problems into a linear system of equation problems, which greatly facilitates the solution of Lagrange multipliers λ. The computational efficiency of LSSVM is higher than that of SVM. Furthermore, LSSVM is equally suitable for classification and regression tasks in high-dimensional input spaces and can be extended to unsupervised learning and recurrent neural networks.

The main description of the CETE evaluation model used in this paper is as follows: a nonlinear mapping $\varphi(\mathbf{x_i})$ is chosen to map the sample vector with n-dimensional input data as x and one-dimensional output data as y $[(x_1, y_1), \ldots, (x_i, y_i), \quad \mathbf{x_i} \in \mathbf{R}^n, \; y_i \in \mathbf{R}, \quad i = 1, 2, \ldots, m]$, from the original space to the high-dimensional feature space. The regression equation of LSSVM is shown in the following equation:

$$y_i = f(\mathbf{x_i}) = \boldsymbol{\omega}^T \cdot \varphi(\mathbf{x_i}) + b. \tag{1}$$

In the above equation, ω is the weight vector and the constant b is the bias term. The optimization problem of LSSVM is shown in the following equation:

$$\min \frac{1}{2}\boldsymbol{\omega}^T \cdot \boldsymbol{\omega} + \gamma \cdot \frac{1}{2}\sum_{i=1}^{m} \xi_i^2. \tag{2}$$

In the above equation, γ is the regularization parameter and ξ is the error variable. Compared to SVM, the constraints of LSSVM are different, as shown in the following equation:

$$y_i = \boldsymbol{\omega}^T \cdot \varphi(\mathbf{x_i}) + b + \xi_i^2, \; i = 1, 2, \ldots, m. \tag{3}$$

The inequality constraint of the SVM is replaced by an equation constraint, and the Lagrange function is constructed for the solution, as shown in the following equation:

$$\begin{aligned} L(\boldsymbol{\omega}, b, \xi, \lambda) = {} & \frac{1}{2}\boldsymbol{\omega}^T \cdot \boldsymbol{\omega} + \gamma \cdot \frac{1}{2}\sum_{i=1}^{m} \xi_i^2 \\ & - \sum_{i=1}^{m} \lambda_i \left[\boldsymbol{\omega}^T \cdot \varphi(\mathbf{x_i}) + b + \xi_i - y_i\right]. \end{aligned} \tag{4}$$

In the above equation, λ_i is the Lagrange multiplier. The optimal value is calculated under the Karush–Kuhn–Tucker (KKT) optimization condition. The equation constraint is shown in the following equation:

$$\begin{cases} \dfrac{\partial L}{\partial \boldsymbol{\omega}} = 0 \longrightarrow \omega = \sum_{i=1}^{m} \lambda_i \varphi(\mathbf{x_i}) & , \\ \dfrac{\partial L}{\partial b} = 0 \longrightarrow \sum_{i=1}^{m} \lambda_i = 0 & , \\ \dfrac{\partial L}{\partial \xi} = 0 \longrightarrow \lambda_i = \gamma \xi_i , \\ \dfrac{\partial L}{\partial \lambda} = 0 \longrightarrow \boldsymbol{\omega}^T \cdot \varphi(\mathbf{x_i}) + b + \xi_i - y_i = 0. \end{cases} \tag{5}$$

By eliminating $\boldsymbol{\omega}$ and ξ in the above equation, the quadratic optimization problem is replaced by solving a linear system of equations, and the result is calculated as in the following equation:

$$\begin{bmatrix} 0 \\ \mathbf{Y} \end{bmatrix} = \begin{bmatrix} 0 & \mathbf{Q}^T \\ Q & \boldsymbol{\Omega} + \gamma^{-1}\mathbf{I} \end{bmatrix} \begin{bmatrix} b \\ \lambda \end{bmatrix}. \tag{6}$$

In the above equation, $\mathbf{I}$ is the identity matrix; α is a support vector; $\mathbf{Y} = [y_1, y_2, \ldots, y_m]^T$; $\mathbf{Q} = [1, 1, \ldots, 1]^T$; $\boldsymbol{\Omega}$ represents the inner product of the kernel matrix, $\boldsymbol{\Omega} \in \mathbf{R}^{m\times m}$, and $\boldsymbol{\Omega}_{ij} = \varphi(\mathbf{x_i})^T \varphi(\mathbf{x_j}) = K(\mathbf{x_i}, \mathbf{x_j})$, $i, j = 1, 2, \ldots, m$. Based on the kernel function in the original space, the regression of LSSVM is obtained function for the following equation:

$$y = \sum_{i=1}^{m} \lambda_i K(\mathbf{x_i}, \mathbf{x_j}) + b. \tag{7}$$

To circumvent the dimensional catastrophe, a radial basis kernel function commonly used in LSSVM is introduced instead of the inner product operation in the high-dimensional feature space. The radial basis kernel function is shown in the following equation:

$$K(\mathbf{x_i}, \mathbf{x_j}) = \exp\left(-\frac{(x - x_i)^2}{\sigma^2}\right). \tag{8}$$

In the above equation, σ represents the kernel function width. The generalization ability of LSSVM can be enhanced by optimizing two parameters, γ and σ . When LSSVM is used for University English teaching evaluation, the particle swarm algorithm can be used for the parameter finding problem, and the specific evaluation process is shown in Figure 2.

2.3. Parameter Optimization Based on PSO. Parameter selection is an important research direction in the field of LSSVM research. Many methods can be used to determine γ and σ, but there are deficiencies in memory and time. Particle swarm optimization (PSO) algorithms have the advantages of being less prone to local minima, easy to implement, and with fewer tuning parameters. Thus, PSO is often used to solve nonlinear, nonintegrable, and multimodal problems. In PSO, each potential solution to the optimization problem is called a "particle." Each particle has its own stance and velocity (which determines its direction of flight and distance) and an adaptation value determined by the function being optimized.

A population of m particles is set up in a d-dimensional search space, where the optimal position of particle i searched in the space is described by $\mathbf{p_i}$, $\mathbf{p_i} = [p_{i1}, p_{i2}, \ldots, p_{i\,d}]$; the velocity is described by $\mathbf{v_i}$, $\mathbf{v_i} = [v_{i1}, v_{i2}, \ldots, v_{i\,d}]$; the position of particle i is described by $\mathbf{x_i}$, $\mathbf{x_i} = [x_{i1}, x_{i2}, \ldots, x_{i\,d}]$; the optimal position searched for in the total population is described by $\mathbf{p_g}$, $\mathbf{p_g} = p_{g1}, p_{g2}, \ldots, p_{g\,d}$. The method to update the particle position and velocity is given in the following equations:

$$x_{i\,d}^{k+1} = x_{i\,d}^{k} + v_{i\,d}^{k+1}, \tag{9}$$

$$v_{i\,d}^{k+1} = \omega v_{i\,d}^{k} + c_1 r_1 \left(p_{i\,d} - x_{i\,d}^{k}\right) + c_2 r_2 \left(p_{g\,d} - x_{i\,d}^{k}\right). \tag{10}$$

Among them, ω is the inertia weight coefficient; c_1 and c_2 are the acceleration constants; k is the optimization algebra; $v_{i\,d}^{k}$ and $x_{i\,d}^{k}$ are the search velocity and position of the particle in the space at algebra k; r_1 and r_2 are the random numbers. The process of optimizing the parameters γ and σ by PSO is as follows:

(1) Normalize and preprocess the CETE evaluation data
(2) Set the parameter values
(3) Initialize processing
(4) Set the individual extreme value $P_{i\text{best}}$ and the global extreme value g_{best}, and calculate the adaptation value of each particle according to its current position, $f = \sum_{i=1}^{N} |y_i - y_1'|$, where N is the total number of samples
(5) In order to generate new populations, update the particle positions and velocities according to equations (9) and (10)
(6) Solve for the fitness value f for each particle within the new population
(7) Compared with the previous optimal speed and optimal position of the population, if it is excellent, the conversion will be implemented, otherwise, no adjustment will be made
(8) If the optimal ending condition is not met, we need to make the number of iterations $t = t + 1$ and return to Step 4 to find the optimal solution

2.4. Evaluation Process. Combined with the evaluation index system of College English teaching effect, a College English teaching effect evaluation model based on the particle swarm optimization algorithm and support vector machine is established. The flowchart of the model is shown in Figure 3.

The input sample of LSSVM is the value of CETE evaluation data, which is from the expert rating. And the evaluation results are obtained through the operation of the

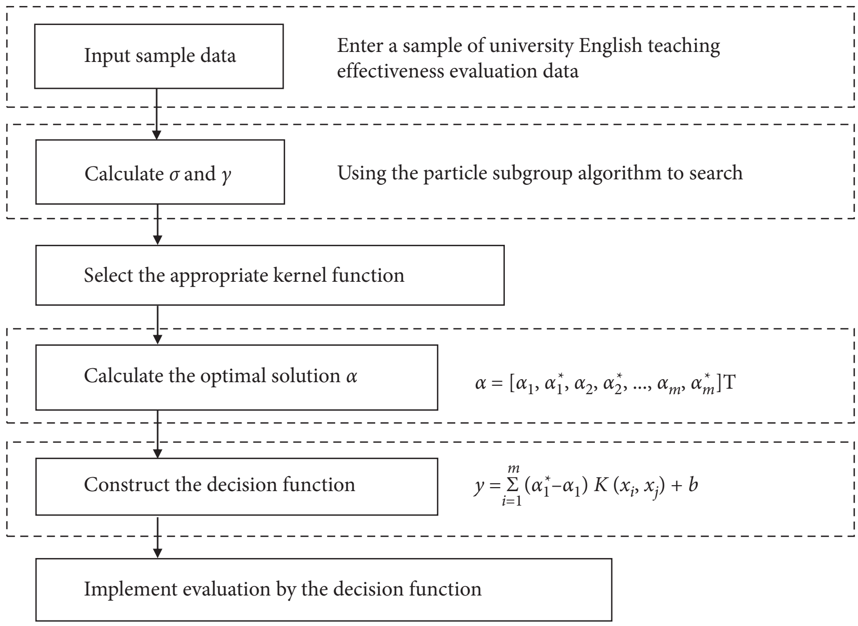

Figure 2: Evaluation model main process.

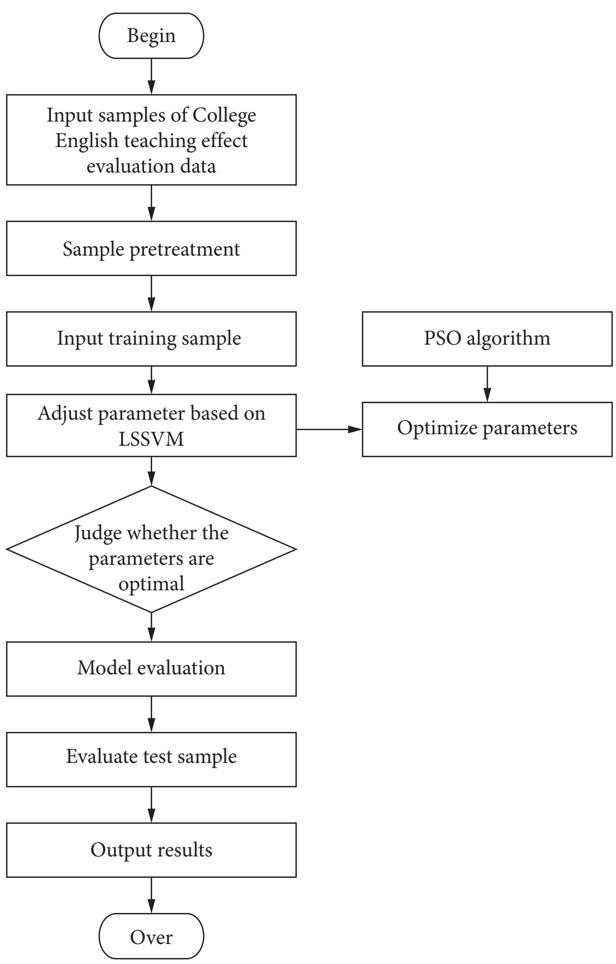

Figure 3: Flowchart of CETE based on the improved support vector machine algorithm.

SVM algorithm. This paper optimizes the evaluation algorithm by comparing the evaluation results before and after adding the PSO algorithm. The PSO algorithm mainly solves the optimal solutions of kernel function parameters and regularization parameters of LSSVM, and then optimizes the process of CETE evaluation. It judges whether the existing parameters are the optimal solution through the IF function. If the result is yes, the test samples are evaluated, and the results are output. If the result is no, the particle swarm optimization algorithm needs to be used to readjust the parameters to the optimal solution. The above process is a machine learning process, and the computer realizes the purpose of automatic tuning through its own learning.

3. Experimental Results and Analysis

This paper selects the English classroom teaching effect of Shangqiu Institute of Technology as the research object and collects sample data according to the evaluation index of CETE. Through the actual situation of College English teaching and the evaluation of College English teaching effect by experts, we can get the quality level of College English classroom teaching and 200 data samples for testing. In the model building process, this paper chooses the Gaussian radial basis function as the kernel function.

The training data of each degree of the six faults are input to the LSSVM regressor for learning, while the PSO algorithm is used for multiobjective optimization of the regularization parameters and kernel function parameters. The population size of PSO is set to 200, the learning factor to 1.49, the maximum number of iterations to 1000, and the inertia weight to 1 initially. The final choice of the best model parameters is $(\gamma, \sigma^2) = (2316.57, 224.46)$, $b = 9.93$. The regression performance of the model is evaluated by the ratio of the number of correct model predictions to the total number of samples, as shown in the following equation:

$$\text{accuracy} = \frac{\mathrm{TP} + \mathrm{TN}}{\mathrm{TP} + \mathrm{FP} + \mathrm{FN} + \mathrm{TN}}. \tag{11}$$

In order to verify the effectiveness of the PSO-LSSVM method for CETE assessment, we also use the BP neural network [17] and gray target decision method [18] for comparison testing. Three methods are used to test the experimental dataset to obtain their accuracy calculation results, as shown in Table 2 and Figure 4. As can be seen from Table 2, the average evaluation accuracy of the method in this paper is 96.26%, which is 5.36% and 14.29% higher than that of the BP neural network and gray target decision, respectively. Therefore, the PSO-LSSVM method has a very superior degree of accuracy and scientific performance.

Next, we performed 20 experiments on 10 datasets using the three methods, and the time used for the three methods (test time and training time) within the experiment was calculated while the average value was selected. The results of the comparison of the three methods are shown in Figures 5 and 6.

From the comparison results of Figures 3 and4, it can be seen that POS-LSSVM has obvious advantages over the other two methods in terms of time efficiency, the training time and testing time of this method are the lowest, the average training time is as low as 15 ms, and the average testing time is as low as 5 ms. Compared with the BP neural network, its training time saves 8 ms and its test time saves 5 ms; compared with gray target decision, its training time saves 3 ms and its test time saves 4 ms.

4. Teaching Optimization Design

The purpose of this paper is to come up with the most sensitive influencing factors through the constructed CETE evaluation model and then proposing some targeted ways to improve the effectiveness of English teaching. After further questionnaires and armor-piercing interviews, we conclude that A_{11}, A_{12}, A_{14} , and A_{21} play a more important role for English teaching. The four indicators were moved up and down by 5% and 10%, respectively, and the magnitude of the impact of each move on the evaluation results is shown in Figure 7. To facilitate the analysis of the degree of change in the evaluation results, the rate of change is expressed using the absolute value of the true value. Figure 7 illustrates that A_{11} and A_{14} have a higher degree of influence on the evaluation results compared to A_{12} and A_{21}, which suggests that the optimization of CETE in this paper focuses on both course content and teacher skills [19].

In language learning, interests will be a great help to students. Therefore, we must find suitable methods to improve teachers' literacy and enrich teaching contents so as to stimulate the interest of student and improve the teaching effect [20]. Starting from the reality of STL, this paper mainly improves College English teaching through the integration of information technology and curriculum design.

4.1. Observation Dimension of Curriculum Design. Before the beginning of curriculum optimization, this paper observes the English curriculum of SIT colleges and universities, obtains research materials by means of field observation, and mainly observes the curriculum design of English teaching in SIT colleges and universities, the application of technical tools, and the integration of technology and curriculum content. The specific observation dimensions include teaching objectives, learning situation, teaching content, teaching media and curriculum materials, and teaching procedures.

In terms of teaching objectives, SIT teachers focus on cultivating college students' basic knowledge and skills of English audio visual according to the syllabus and curriculum requirements and pay attention to the cultivation of students' emotions, attitudes, and values in the teaching curriculum planning. However, it does not focus on cultivating students' English thinking and lacks the cultural elements in English function. In terms of learning, SIT teachers regard students as the learning center. In the whole process of English teaching, teachers pay enough attention to students' learning status and performance. However, as a freshman of SIT, the basic knowledge of English is not solid, and the knowledge structure is not systematic and perfect. Teachers' teaching rhythm is not synchronized with students' learning status and ability. As a result, teaching is hindered. In terms of teaching content, SIT teachers have the phenomenon of following the book, lack of effective design of teaching content, and no fine processing and expansion of knowledge and skills. The teaching content adheres to the textbook itself, resulting in the lack of interest in the course. In the application of teaching media and curriculum materials, SIT classrooms are equipped with advanced teaching technology tools, but teachers are not well applied to practical teaching, only as the presentation and display of curriculum materials, and curriculum design lacks theoretical guidance.

In addition, in the actual teaching process, teachers only use textbooks, markers, and whiteboards for teaching. Therefore, teaching technology cannot give full play to its maximum function, and it is in a state of separation from the whole teaching process. In terms of teaching procedures, SIT teaching procedures tend to be old, mainly including review, main curriculum, practice, summary, and home work There are some practical problems in this teaching procedure, which should be optimized to add links between teachers' activities and students' learning activities.

Thus, the application framework of teaching links, activity forms, and technical tools of the specific observation dimension of SIT English course is obtained, as shown in Figure 8. In the review session, the teacher summarizes and reviews the basic English knowledge and skills learned in the previous course, including cognition, understanding, and skills. In the main curriculum link, the teacher will present the prepared course content in writing and oral form according to the teaching requirements, mainly including theme introduction, vocabulary obstacle removal, key explanation, text explanation, and extracurricular knowledge expansion. In the practice link, teachers test the students'

Table 2: Comparison of evaluation accuracy results.

Dataset	PSO-LSSVM (%)	BP neural network (%)	Gray target decision (%)
1	96.89	92.30	84.55
2	95.72	88.76	83.43
3	97.90	92.12	83.08
4	94.34	93.62	80.89
5	96.41	87.90	79.63
6	98.02	89.54	82.60
7	95.23	90.21	78.15
8	96.29	92.88	83.42
9	94.37	90.49	78.94
10	97.46	91.25	85.03

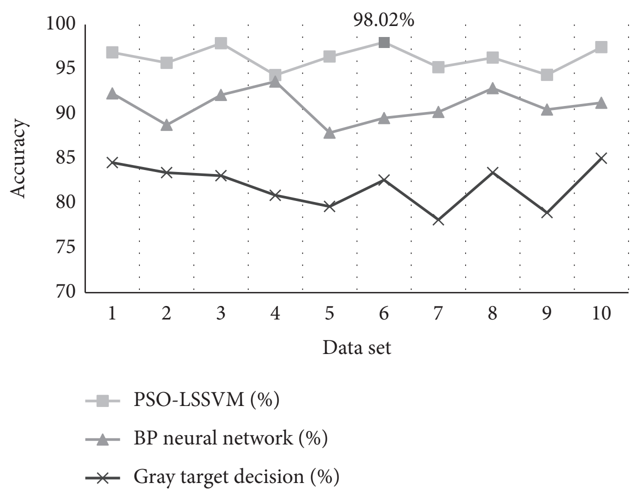

Figure 4: Comparison of evaluation accuracy results.

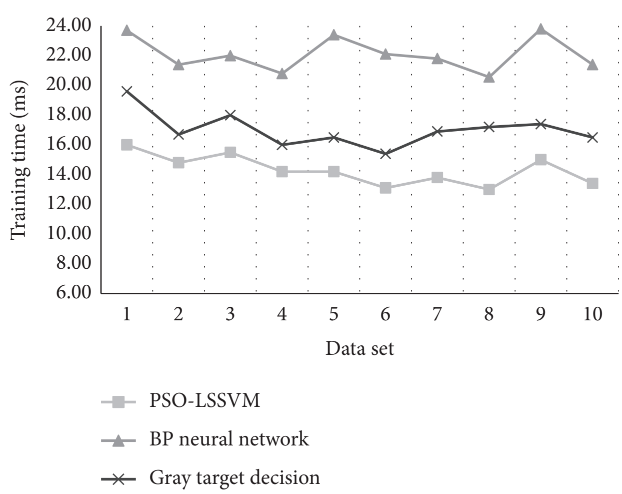

Figure 5: Comparison results of training time of different models.

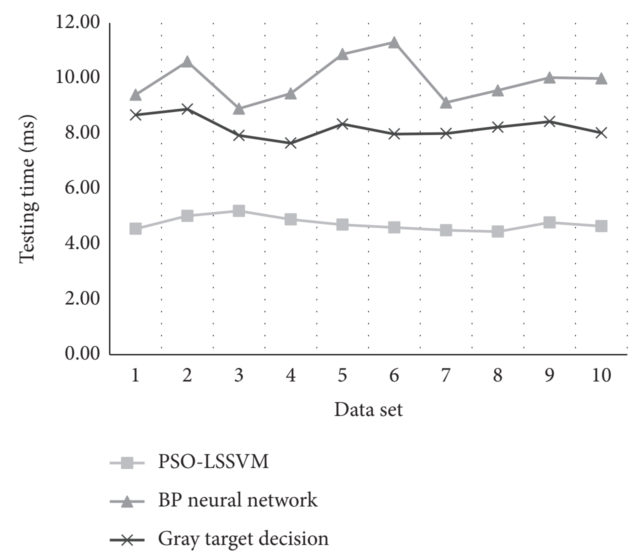

Figure 6: Comparison results of testing time of different models.

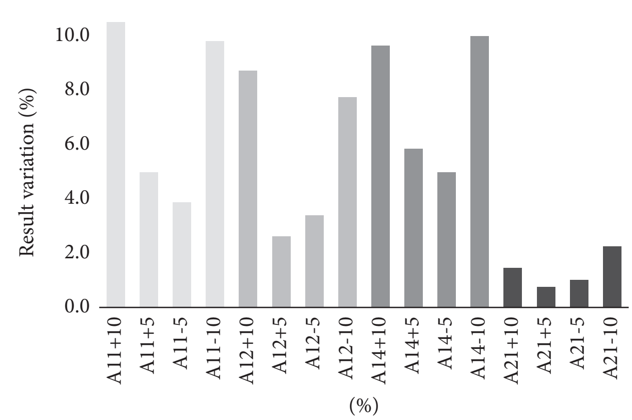

Figure 7: Sensitivity analysis of important indicators.

learning of course knowledge in groups by random roll call and random inspection, and restate and explain the knowledge points with high error rate. In the summary section, teachers apply the consolidation method to review the course and repeat the key and difficult points of the course to understand the students' understanding of knowledge. In the home work link, the teacher assigns homework after class. The types of homework include dictation and recitation of key words, and flexible collocation and application of phrases and sentence patterns.

4.2. Optimization and Perfection of Teaching Procedure. This paper chooses an optimized program guided by the integration of information technology and curriculum, mainly to address the current situation of outdated teaching

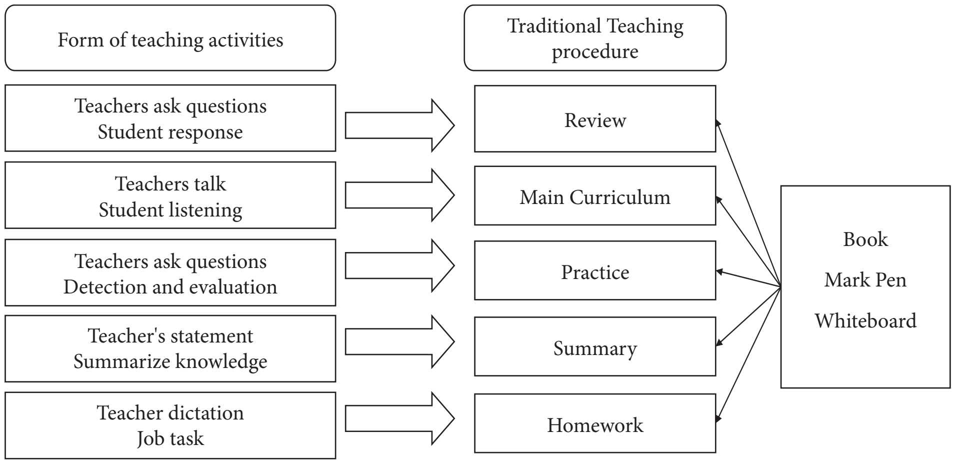

Figure 8: Teaching activity procedure of SIT universities before optimization.

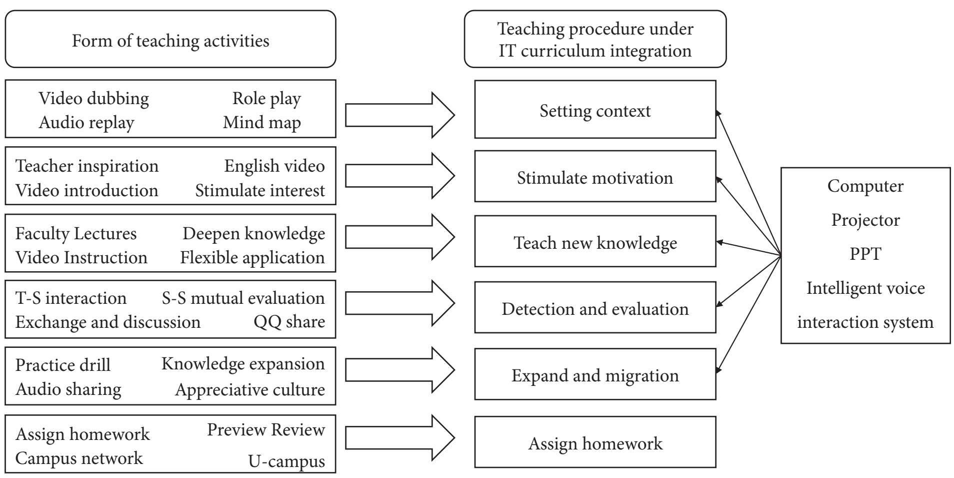

Figure 9: Teaching activity procedures under IT curriculum integration.

design, fragmentation, and disconnection between technological tools and actual teaching. The aim is to enhance the comprehensive ability of teachers, improve learning interest of students, and enhance the coherence of course content and teaching quality in future education and teaching. The main dimensions of teaching optimization design include the whole teaching process, using technology concepts and technology tools to integrate teaching dimensions. Every aspect of teaching is assisted and facilitated by the application of technology; the technology concept fully integrates the whole teaching process, the technology tools are no longer idle, and they are more efficiently integrated with teaching.

The intelligent voice system is integrated into all stages of the whole course teaching process to enrich the teaching content so that students can carry out role playing, audio and video appreciation, and other activities. This pedagogical optimization focuses on the teacher-led-student-subject role in the teacher-student teaching role position dimension. Students learn under the inspiration, guidance, and teaching of the teacher. Then, under the guidance of this theory of teaching-learning relationship, the optimization of teaching and learning under the guidance of IT and curriculum integration is achieved through the use of technological tools, pedagogical aids, and the integration of subject content concepts into the whole teaching process. In general, the study provides a careful design and detailed analysis of the procedures of teaching activities so that the optimized teaching design can be more effective. The specific contents of teaching optimization and the integrated application of information technology are shown in Figure 9.

5. Conclusion

The quantitative nonlinear functions between the CETE and each evaluation index are complicated. The complex mathematical relationships lead to subjectivity in the evaluation scores, which affects the objectivity and fairness of the evaluation. In order to accurately evaluate the effectiveness of College English teaching and improve the overall level of College English teaching, this paper studies the evaluation model of College English teaching effectiveness based on PSO-LSSVM. The average accuracy of the evaluation model in ten datasets is 96.26%, which has high advantages and is nearly 6% higher than that of the BP neural network. The average training time is 15 ms, and the average test time is

5 ms. The experimental results show that this method has the highest evaluation accuracy, short evaluation time, and the best evaluation results. Based on the method of this paper, it can improve the optimization plan for English teaching effect, which is of great practical significance for the improvement of College English teaching level.

During the implementation of this study, the concept of information technology and curriculum integration is applied to guide teaching and learning and to carry out teaching practices. This a priori concept optimizes and improves the whole teaching system, and each component of the teaching system incorporates the concept of technology integration. At the same time, it focuses on the integration of technology, pedagogy, and subject content. As a result, SIT is optimized, and students' English listening and speaking skills are improved.

Due to the limited time and energy, there are still some deficiencies to be further improved. Firstly, in order to improve the generalization of the research, we need to try to apply better methods to the in-depth study of College English teaching evaluation index system in future research so as to make it complete and more scientific. Secondly, more experimental datatests are carried out for the method in this paper, and the method is continuously optimized in the test. Finally, it is hoped that the in-depth study will apply better methods to College English teaching and make the evaluation accuracy and efficiency better.

Data Availability

The labeled dataset used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Design of a Variable Frequency and Energy Aeroengine Ignition Device Based on MCU

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That the aeroengine ignition device's ignition properties are set as a rule of thumb causes the waste of ignition device's resources, low efficiency of aeroengine's operation, and short service life of plugs. In this paper, a variable frequency and energy aeroengine ignition device is developed for improving aeroengine combustion chamber's ignition properties. The STC89C52 MCU was chosen as the device's core controller. Power supply circuit, MCU and external circuit, IGBT drive circuit, boost circuit, current-voltage monitor circuit, and discharge circuit are all part of the hardware circuit. Because the MCU is in charge of driving the IGBT and discharging the capacitor, the device can accurately generate a corresponding frequency output signal. It also creates frequency control and energy control modules, both of which can adjust ignition properties according to user needs. The ignition device proposed in this paper is stable and lighter and has a predetermined frequency and energy. It lays the groundwork for improving the aeroengine's ignition reliability.

1. Introduction

1.1. Research Status

1.1.1. Research Actuality. At present, many domestic ignition devices adopt reverse flyback converters to boost the voltage [1–3]. They use a gas discharge tube to discharge electricity. A few advanced ignition devices use MOSFET to boost the voltage [4–6]. That some western countries have begun to develop electronic ignition devices, which are small and light, and have precision frequency, laying a perfect foundation for the subsequent study of variable frequency and energy ignition devices.

The performance of domestic high-temperature semiconductors is very low, which cannot follow the desire of requesting large aeroengine high-temperature working environment [7, 8]. At present, domestic large aeroengine ignition device mainly uses a mechanical resonance inverter booster transformer to succeed inverter booster. It adopts gas discharge tubes as discharging control switches [9, 10]. Only some small engines, power plants, and starters which require low-temperature working environment use semiconductor power tube boost circuit [11].

1.1.2. Trend. Aeroengine fuel must be ignited by an ignition system and burned, which serves as a source of energy. Engines must have a low rate of controlling in-flight shutdown and good in-flight ignition capability. The ignition system [12, 13] is a critical component of the engine's starting and restarting process, and its operating characteristics and abilities have a direct impact on whether engines start and restart successfully, as well as the engine's overall safety. The following is a summary of the future development trend of domestic aeroengine ignition systems:

(1) From inductive energy storage to capacitor energy storage ignition device: the ignition device, which has a special energy storage device inside, is a key component of energy storage and release. The stored energy of an inductive energy storage ignition device is typically several dozens of millijoules, with high and uncontrollable discharge frequencies. The stored

energy of a capacitor energy storage ignition device can be several dozens of joules, with low and controllable discharge frequencies. The inductive energy storage system's stored energy is used for indirect ignition, which is heavy. The capacitor energy storage system's stored energy is used for direct ignition. Unless an old machine type is isolated, new machine types now use a capacitor ignition system rather than an inductive system. By controlling the energy-storing capacitance charge, the capacitance discharge ignition system accumulates enough voltages. It releases energy into the ignition spark plug by capacitance discharging instantaneously [14].

(2) From mechanical to electronic ignition device: The development of the ignition system is also the development of electronic components. Contact ignition device grows into contactless ignition device. And analog ignition device grows into digital ignition device.

The main difference between a contact and a contactless ignition device is whether or not there are any devices inside, such as a voltage converter, that have contact vibration. The DC-AC [15] contact ignition device with electromagnetic contact vibration has electromagnetic conversion abilities of vibration transformer coils, and low-voltage direct current becomes high-voltage pulse current. The diode then rectifies the signal and charges the energy-storing capacitance. When the capacitance voltage reaches the discharge tube's breakdown voltage, the discharge tube breaks down, releasing energy into the spark plug and cable. An electric spark is produced by the ignition spark plug. Then do it all over again. The operational life of a contact ignition device is shorter than that of a contactless ignition device due to the device's moving mechanical elements.

When the contactless ignition device is connected to a DC supply [16, 17], low-voltage DC power is converted to high-voltage AC power by filter circuit and DC converter circuit. It is rectified by time jitters of the diode and charges the energy-storing capacitance. When the voltage of the capacitance reaches the breakdown voltage of the discharge tube, the discharge tube breaks down. It discharges via the discharge tube and the spark plug generates an electric spark. The contactless ignition device is converted mainly by transistor devices.

1.2. Research Purpose. The ignition device, which is common in various aeroengines, is a control device that provides a rated voltage pulse for the combustion chamber in the aeroengine. In the aeroengine system, it is one of the most important control components. The ignition device ensures that the aeroengine system operates safely and reliably under a variety of external environmental conditions. A new type of revolutionary ignition device is a variable frequency and energy ignition device. Technology research on safe variable frequency and energy ignition device is underway in advance of the application needs for domestic aeroengines. The MCU and pulsed power key technologies are primarily used in its technology. It is a high-voltage pulsed power device that is required for concurrent hardware and software design jobs involving variable frequency and energy.

The purpose of this paper is to design a variable frequency and energy aeroengine ignition device [18]. Variable frequency and energy ignition technology is based on the traditional ignition system and is also advanced and intelligent. The big difference between the new system and the traditional system is the possession of abilities of variable frequency and energy. The core technology of the device is solid-state ignition technology. It uses semiconductor components instead of components such as contact transformer and gas discharge tube in traditional ignition technology. It has greatly improved. It has many advantages over traditional ignition device in electromagnetic compatibility, power adaptation, output stability, lifespan, reliability, and maintainability. In addition, variable frequency and energy ignition device adds control circuit based on solid-state ignition circuit to give control of frequency and energy. It can also provide a corresponding frequency electric spark for aeroengine in different climates.

A variable frequency and energy aeroengine ignition device can offer multiple combinations of frequency and energy [19]. The optimum ignition parameters can be progressively determined by matching with other engines under different operating conditions in the experiment. We can craft an ignition system limiting stored energy and a combustion chamber limiting ignition spark frequency by matching with each other from the minimum to the maximum. We determine the best composite value between stored energy and spark frequency under different operating conditions by carrying out experiments progressively. The ignition parameter under different engine operating conditions is given by further control logic. We can enhance start ignition reliability under different engine conditions effectively.

The function of variable frequency and energy is the leading technology in the ignition field, and the frequency and energy of traditional ignition are flat. When demand from customers changes, a new kind of device needs to be redesigned. It wastes time and cost. The variable frequency and energy ignition device designed in the paper has 75 kinds of combinations of frequency and energy. It is used more and more widely. That the aeroengine ignition device's ignition properties are set as a rule of thumb causes the waste of ignition device's resources, low efficiency of aeroengine's operation, and short service life of plugs. In this paper, a variable frequency and energy aeroengine ignition device is developed for improving the aeroengine combustion chamber's ignition function.

2. Hardware Design

The device uses MCU as the core controller. The MCU circuitry can simplify the control circuit and reduce the failure rate of the circuit. The principle block diagram of the ignition device designed in this paper is shown in Figure 1. The ignition device has a total of 15 kinds of frequency that

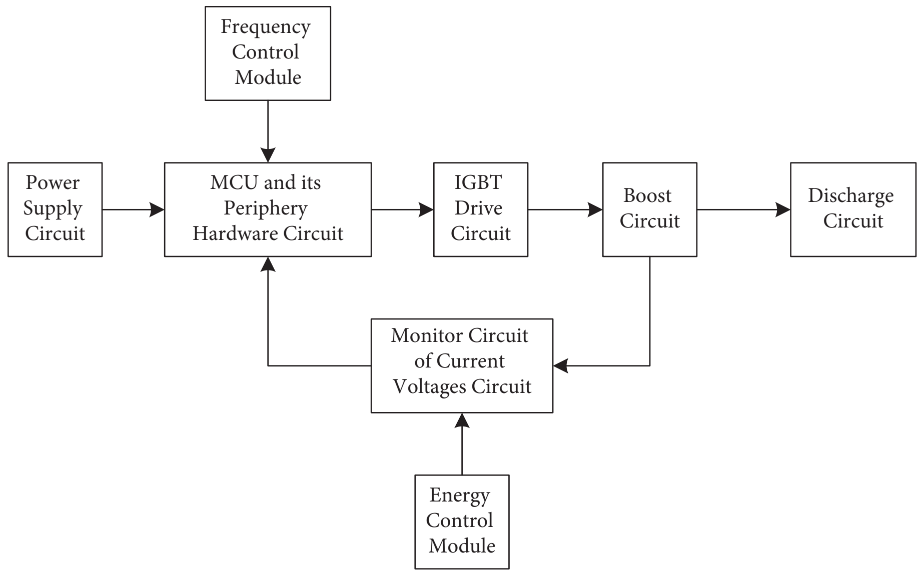

Figure 1: Block diagram of the variable frequency and energy ignition device.

ranges from 1 Hz to 15 Hz and 5 kinds of energy that ranges from 1 J to 5 J.

The variable frequency and energy ignition device works as follows: power source 28 VDC across the power circuit provides stable voltages of +24 V, +12 V, and +5 V, which provides a stable and reliable power for various follow-up modules. The frequency control module causes MCU to output corresponding frequency PWM signals [20]. The signal is then amplified by the IGBT driver module to generate enough high driving voltage. The voltage drives boost circuit made up of IGBTs. Then the diode conducts and the energy-storing capacitance is charged up exponentially. The MCU detects the voltage across the energy-storing capacitance by the monitor circuit of current-voltage circuit during charging. When the voltage is higher than the value set by the MCU, the MCU control ignition triggers port output high level, which triggers the discharge circuit. Then a steady stream of energy in the energy-storing capacitance is released by coil inductance, which breaks down the switch. At last, the ignition device realizes the ignition function. The frequency control module adjusts the frequency and the energy control module adjusts the energy.

2.1. Design of the Power Supply Circuit. The ignition device's input voltage is 28 VDC. The device adopts a 7800 series three-end integrate device that provides stable voltages of +24 V, +12 V, and +5 V for follow-up circuits. Its circuit schematic is shown in Figure 2. We put the filter capacitors C1~C6 before the input of the circuit to remove clutter from the input. We put the vibration-proof capacitor C7 after the output of the circuit to remove clutter from the input. At last, stable voltages of +24 V, +12 V, and +5 V are obtained, respectively.

2.2. MCU and Its Peripheral Hardware Circuit. The STC89C52 MCU of 8051 series is chosen, which is powerful, port richly functional, cheap, and mainstream. The circuit is core to MCU STC89C52 and the switching circuit and A/D converter circuit are designed for its peripheral circuit. The switching circuit selects the silicon chip CD4076, which is one of the sixteen analog switches, in order to choose frequency that ranges from 1 Hz to 15 Hz. The A/D converter circuit selects A/D converter TLC2543 [21]. It digitizes voltages obtained by the monitor circuit of the current-voltage module. Then the result will be input to the MCU. In order to perform well, we should speed up the running rate of the MCU. So 11.0592 MHz crystal is selected. Then the MCU can generate rectangle signals of corresponding frequency by its timer.

MCU hardware circuit is shown in Figure 3. Port P0.0 is the output interface of the PWM signal. Port P0.1 is voltage comparator circuit interface. Port P0.2 is ignition trigger interface. PWM-driven control adjusting theory is an operation that the power supply is opened and closed with some regular frequency. PWM is controlled by changing the length of switching power supply time. PWM frequency is changed by changing the timeframe in the ignition control system to generate PWM signal. So PWM is described as switch-driven device.

2.3. IGBT Drive Circuit. The maximum of the rectangle signal outputted by the MCU is +5 V, which is not sufficient to drive IGBT. So the IGBT drive circuit is needed. It can amplify the rectangle signal to some value which is enough to drive the IGBT. This module uses the silicon chip AST965 as the core controller. The amount of peripheral devices needed is minimal. And it is easy to operate. It can separate control circuits from functional circuits with minimal interference. The IGBT drive circuit is shown in Figure 4. The rectangle signal is input from port 1 and the amplified signal is output from port 8.

2.4. Boost Circuit. The single-ended flyback construction is used in the boost circuit, as Figure 5 shows. A flyback transformer actually is a multiple winding coupling inductance.

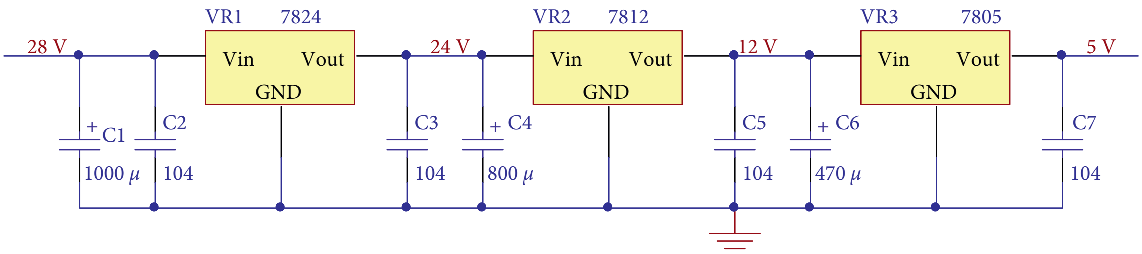

Figure 2: Power supply circuit.

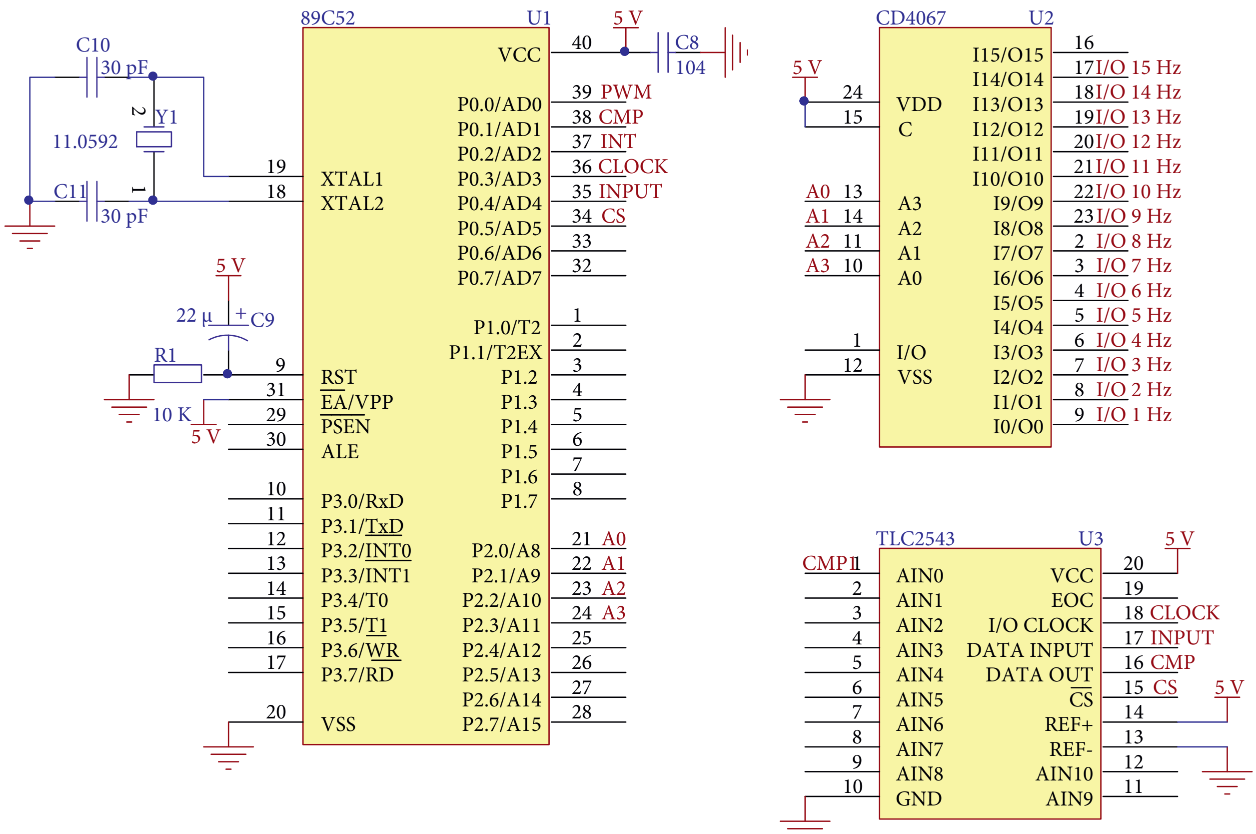

Figure 3: MCU and its peripheral hardware circuit.

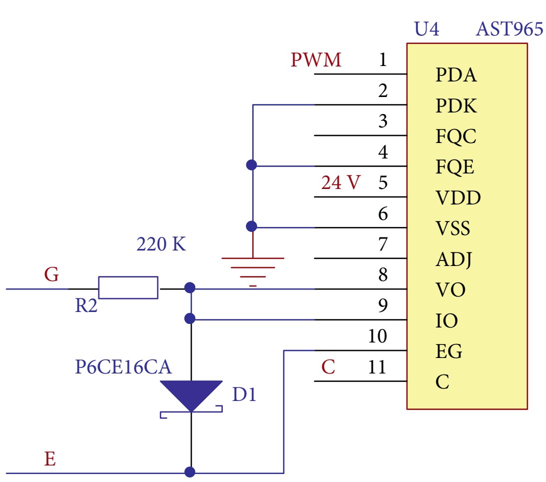

Figure 4: Drive circuit.

The flyback transformer stores energy and it transforms magnetic energy into electricity for transmission. When the IGBT is conducted, the diode is cut off and magnetic field energy is stored in the transformer T1 primary winding. When the IGBT is cut off, the voltage of the secondary winding breaks suddenly and induces a reverse voltage. Then the diode D3 conducts and magnetic field energy in the primary winding is released to the energy-storing capacitance.

During flyback conversion, the transformer has leakage inductance. Then both ends of the IGBT generate peak voltage that disturbs the circuit. So RDC absorbing circuit is designed in this module that inhibits peak voltage.

2.5. Monitor Circuit of Current-Voltage Circuit. The chief function is to monitor the voltage across the energy-storing capacitance. The voltage range of the MCU port is 0–5 V. So

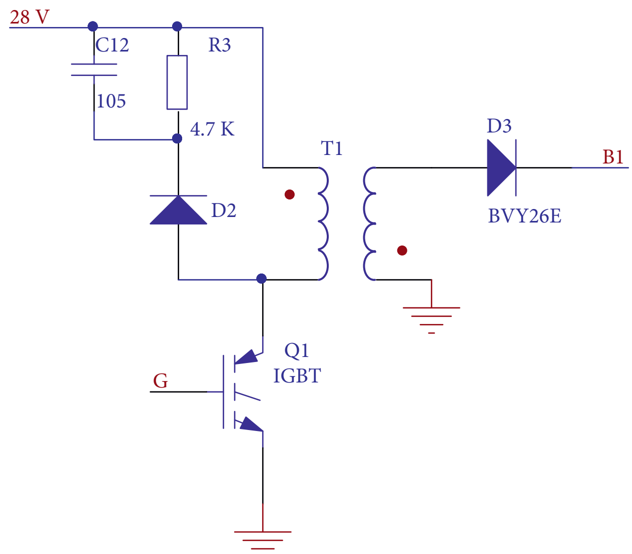

Figure 5: Boost circuit.

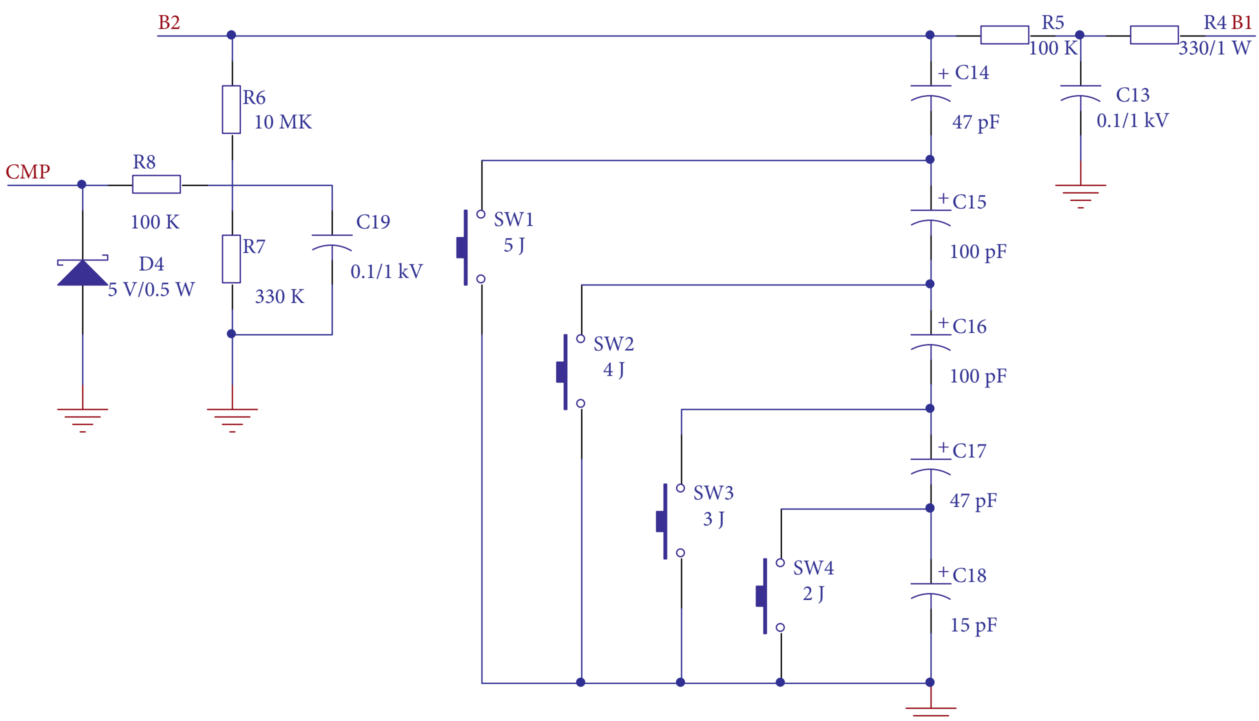

Figure 6: Monitor circuit of the current-voltage circuit.

collected voltage that is divided turns into a signal that can be recognized by the MCU. B1 is the input of the module, which is amplified by the boost module, as Figure 6 shows. It is filtered by the filter capacitor C13. Then it charges the energy-storing capacitance. The voltage across the energy-storing capacitance is divided by the resistors R6 and R7. The voltage across the resistor is just the signal needed to collect. If it is higher than the values set by the MCU, the ignition trigger port outputs high-level signal. If it is lower than the values set by the MCU, the ignition trigger port outputs low-level signal.

Four switches are designed in the monitor circuit of the current-voltage circuit to realize the function of changing energy. C14~C18 are energy-storing capacitors. When no switches are pressed, the energy output of the device is 1 J. When the switch SW1 is pressed, the energy output of the device is 2 J. When the switch SW2 is pressed, the energy output of the device is 3 J. When the switch SW3 is pressed, the energy output of the device is 4 J. When the switch SW4 is pressed, the energy output of the device is 5 J.

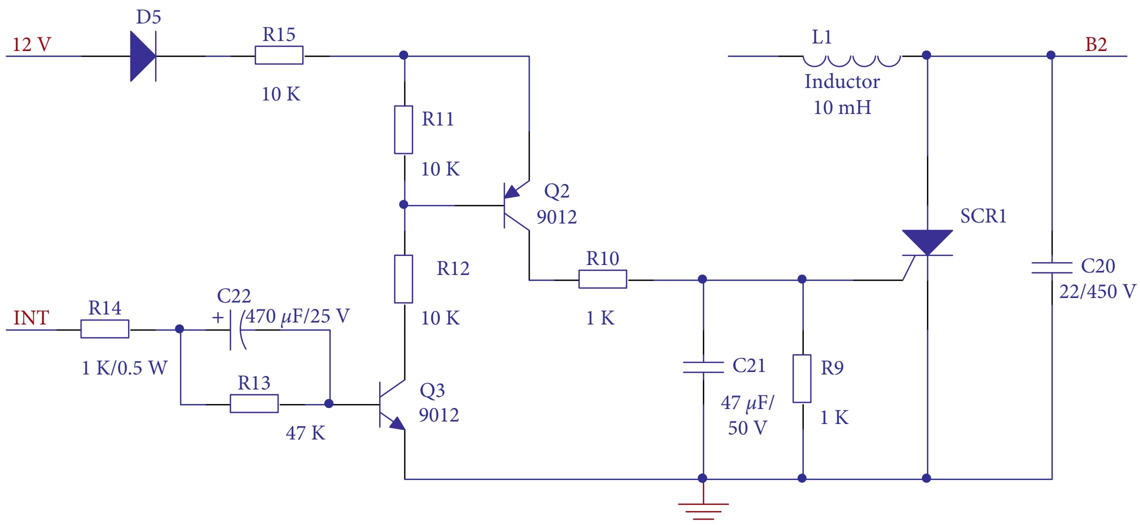

Figure 7: Discharge circuit.

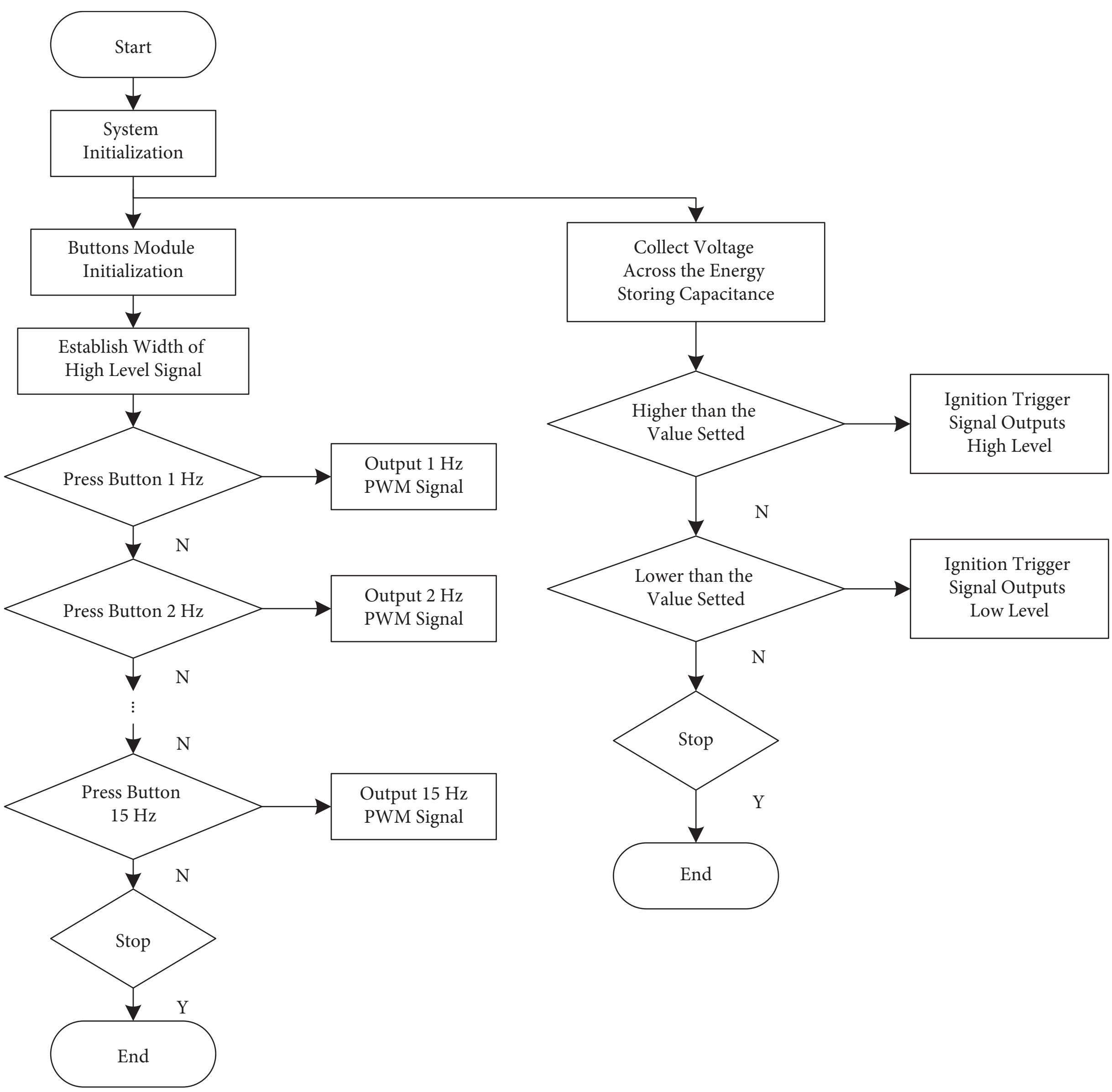

Figure 8: Software flow diagram.

2.6. Discharge Circuit. While the energy-storing capacitance is fully charged, the energy in the capacitor needs to be released to the spark plug as soon as possible in order to realize the ignition function. The SCR is used as a switching device, as Figure 7 shows. When the PWM signal is high, potential differences between the base and emitter region of the triode Q3 are present. Then the triode Q3 conducts. Meanwhile, potential differences between the base and emitter region of the triode Q2 are also present. Then the triode Q2 conducts. At last, the SCR is triggered. As the energy-storing capacitance discharges continuously, the current between the anode and cathode of the SCR reduces gradually. Then the SCR is cut off, and the discharge process of the energy-storing capacitance can be accomplished.

3. Software Design

This section introduces MCU code, which is divided between PWM signal generating and trigger discharging section. The code is downloaded in the MCU through the software Keil uVision [22]. The principal program flow is shown in Figure 8.

The following are the chief functions of the software design:

(1) The software makes port P0.0 of the MCU generate a PWM driving signal.

(2) The software makes the MCU generate a trigger signal. Port P0.1 of the MCU is the comparing port and port P0.1 is the ignition trigger port. When the voltage collected by the monitor circuit of the current-voltage circuit is higher than values set by the MCU, port P2.0 outputs high-level signal. When it is lower than values set by the MCU, port P2.0 outputs low-level signal.

(3) The software control frequency of the PWM signal is outputted by the MCU. The MCU controls frequency by code switches. The range of frequency is from 1 Hz to 15 Hz.

4. Conclusion

In this paper, a variable frequency and energy aeroengine ignition device is designed. It controls the frequency that ranges from 1 Hz to 15 Hz and energy that ranges from 1 J to 5 J. There are 75 kinds of permutations of frequency and energy. The device lays the foundations for the study of the combustion chamber's ignition property and the realization of maximizing the combustion chamber's lean ignition excess air coefficient and shortening ignition lag time. We can adjust the ignition abilities of ignition devices according to engine performance to make the engine reduce power consumption and lighten the flighting burden. I think that there will be a breakthrough in the number range of energy of ignition devices by software in the future. I should research on how to decrease the volume of the device. How to enhance the reliability and electromagnetic compatibility features of ignition devices deserves further investigation.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author does not have any possible conflicts of interest.

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Research Article

An Ant Colony Algorithm Model Construction on the Impact of Urban Real Estate Value and National Economic Changes

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With the continuous development of social economy, urban real estate has gradually become an important commodity for trading, and to some extent, it also affects the trend of the national economy. In view of these limitations and demand, this paper introduces ant group algorithm, by combining the influence of urban real estate changes on the national economic trend; according to the relevant national policy impact, we analyze the national economy changes and fluctuations, try to build a "four-quadrant" model analysis of real estate market impact analysis, and clear national policy on real estate. In order to obtain better economic policies, we promote the healthy and stable development of urban real estate. Simulation experiment proved that ant colony algorithm is effective and supports the change of urban real estate value and national economy.

1. Introduction

With the continuous development of social economy, urbanization is becoming more and more mature, promoting the transaction of urban real estate. Therefore, as an important trading commodity, it will also affect the trend of the national economy to some extent [1, 2]. How to trace the urban real estate and macroeconomic changes is extremely important [3, 4]. Since the reform and opening up, China has gradually formed a socialist market economy system. However, due to its national conditions, it is more special and complex, rather than a single factor affecting the real estate market. Therefore, it cannot be fitted with single linear influence factors [5, 6]. Various economic crises in the world have a certain impact on China's economy. Although strong policies stimulate the economic development of domestic demand, it is still inevitably affected by the economic crisis; especially compared with the economic development of developed countries, there are still certain disadvantages and limitations [7, 8]. How to influence the influencing factors of China's economy, especially for the satisfaction of export and internal demand, and how to achieve China's economic growth? How to effectively develop urban real estate which can truly develop healthy socialist market economy? These are all problems that need to be solved by industry experts, entrepreneurs, etc.

In view of these problems and demand, this paper introduces ant algorithm, by combining the socialist market economy development of real estate and using four quadrant for real estate market changes; according to the relevant national policy influence, we analyze the national economy changes and fluctuation and aim to explore the macroreal estate development and change, for the long-term equilibrium analysis of urban real estate market.

2. Introduction of Ant Group Algorithm

Ant colony algorithm can divide the real estate market accordingly, into the property market and the asset market, and use the corresponding real estate rent and the newly developed construction real estate to establish corresponding connections. The so-called first quadrant is that the property demand determines the corresponding level of real estate rent, the second quadrant represents the asset market, this part is to use the corresponding real estate for capital realization, and the third quadrant is to increase the corresponding amount of new development, to achieve a certain scale of growth. The fourth quadrant is the long-term conversion of the newly developed construction volume to real estate.

2.1. Image Segmentation Feature Extraction. The image segmentation algorithm was designed based on the ant colony algorithm [9–11]. By extracting the image segmentation features as the starting point, the element features required in the image are determined to design the path of the image segmentation.

In an image, including the target background in addition to the desired target, the image segmentation method is to segment the target from the target background. In the process of segmentation, the edge value and noise need to be set, which mainly ensures that the segmentation route of the target is intact and the target required to protect the image from damage. When setting the image segmentation feature, the pixel gray scale is selected as the first feature of the image segmentation, and the pixel gray scale can be used to distinguish the image background from the image target. Entering the pixel gray scale into the colony yields the corresponding values. Identifying the segmentation route and entering the neighborhood gray scale and gradient into the colony give the edge values for image segmentation. The edge values largely control the route and noise point of the image segmentation, so they take the gray scale value and the neighborhood gray scale value and gradient as the auxiliary to determine the segmentation characteristics of the image and input the corresponding segmentation value into the ant group algorithm.

2.2. Build a Mathematical Model of the Ant Colony Search Process. After determining the image segmentation feature, the segmentation feature needs to be input into the ant colony algorithm, so the mathematical model of the ant colony search process is constructed [12–15]. The mathematical model simulates the trajectory of the ant colony searching for food to calculate, which can accurately determine the immediate obstacles in the search process and ensure the accuracy of the calculation results. Set the initial image as X. Each pixel in X forms a set. Set the set as X_j. The values of the elements in the set are not equal. Based on this, the travel path of ants is determined, and the image segmentation path is judged according to the process of ants looking for food.

The distance between x_{in} is arranged, and the distance between ant crawling is shown as

$$d_{ij} = \sqrt{\sum_{k=1}^{m} p_k \left(x_{ik} - x_{jk}\right)^2}, \tag{1}$$

where m represents the number of input image segmentation features. In this formula, the value of m is set to 3; p_k represents the weighted value of the Euclidean distance, and the magnitude of this value depends on the degree of clustering influence of pixels on the image. The distance between each pixel can be obtained by this formula.

Set the clustering radius of the image to r, ph_{ij} is the amount of information on the path of the ant colony, and determine the guiding function formula in the ant colony algorithm to obtain the guiding probability p_{ij}:

$$\begin{aligned} p_{ij} &= \frac{r}{d_{ij}} \\ &= \frac{r}{\sqrt{\sum_{k=1}^{m} p_k \left(x_{ik} - x_{jk}\right)^2}}, \end{aligned} \tag{2}$$

where the clustering radius r is in the numerator and the denominator d_{ij} is the distance, which is fixed. Therefore, the larger the clustering radius r, the larger the value of the guiding probability p_{ij} of the guiding function, that is, the greater the probability of the ant choosing the path and vice versa. According to the guidance probability, p_{ij} value of the guidance function is finally obtained; the ant's travel route is determined, so as to analyze the edge value of the image segmentation.

2.3. Set the Individual Ant Colony Rules. After completing the mathematical model of the colony search process, bootstrap rules were set against each colony for the calculated bootstrap probability values based on 3 features of the image segmentation [16–18].

2.3.1. Gray-scale Value Feature Rule. Gray-scale values are important features that distinguish the target in an image from the image background and can reduce a lot of computational workload when the gray-scale values in the image are determined. When using colony calculation, colonies can be arranged on the same starting point, the first gray-scale value. After then, the first gray-scale value is determined, the mathematical model calculation can be performed as described above, and the bootstrap probability return of the bootstrap function is determined based on the value of the pixel point.

2.3.2. Gradient Characteristic Rules. Gradient features are important features of analyzing critical and noise points, and different gradient images of the target and the background can be obtained according to the gradient, while also determining gradient pixels points in different ant colonies. Setting the number of pixels in different colonies to n, when n is greater than the pixel mean, indicates that the region of the colony is a cluster center. The gradient feature of 0 is set in the cluster center of the image so that the cluster center of the image segmentation can be resolved.

2.3.3. Neighborhood Gray-Scale Value Feature Rule. Unlike gray-scale values, neighborhood gray-scale values are mainly used for the calculation of image segmentation edges, controlling the details of image segmentation and playing an important role in protecting image pixel work. The neighborhood gray-scale value is set to the regional form of 3×3; combined with the gradient characteristics above, the region with gradient characteristics to zero is set to the cluster center, and the neighborhood gray-scale value feature is set to 6, so the corresponding field value can be obtained to determine the image segmentation direction.

2.4. Set Up the Initial Cluster Center. Setting the initial cluster center reduces a lot of computational work, where the colony moves within the specified range. When the initial cluster center is not set, the ant colonies will walk in the image irregularly, without guiding direction and guiding factors, resulting in excessive computational workload. Therefore, when setting the initial arrangement position of the colony, the initial cluster center should be determined, giving the colony a fixed region and reducing the search time.

When setting the initial cluster center, the cluster center may be located at the center or edge of the image and set according to the gradient characteristics of the image. At the edge of the target and background, the number of pixels is large and excessive pixels will result in the gradient value within the region being zero, so when setting the initial cluster center, the pixel number of the edge with the pixel value of the image target and the background as the starting point.

2.5. Implement the Polymorphic Ant Colony Algorithm for Image Segmentation. Through the setting of the initial cluster center, each ant colony is arranged in the cluster center. In the initial cluster center, the movement of the ant colony is irregular and blind. The distance between each pixel is measured, and the distance data d_{ij} are obtained, and a mathematical model is constructed according to the length of the distance. In this model, the movement of the ant colony mainly uses pheromone to calculate the path, calculates and analyzes the probability according to the movement of the ant colony, and obtains the path of the ant colony through the obtained probability, so as to realize the image segmentation of the polymorphic ant colony algorithm.

3. Principle of Macropolicy and Principle of Real Estate Industry

The continuous development of our economy, the price of real estate is very obvious, especially for economic growth, domestic market domestic demand, and urban real estate as a new stimulus consumption growth point, and demand is very obvious, as shown in Figure 1; in the domestic real estate market, with the growth of the demand curve in the first quadrant of ant algorithm, the real estate rent level and demand will increase at the same time. In particular, for the increase of the rent level in the real estate market, the government has issued various policies, such as tax cuts and preferential ways to encourage real estate transactions, leading to an increase in the price of real estate assets. Therefore, macroeconomic growth will make the residential market develop diffuse, as shown in Figure 2.

However, in the actual development process, the real estate industry has experienced overheated real estate investment in some areas. The prosperity of real estate has exceeded the development level of the local economy, showing the situation and characteristics of the mismatch with the economic development. Therefore, the state uses the corresponding policies, legal and administrative means to treat them differently, realizes the regulation of tax, interest rate, foreign investment, land, and other aspects, and realizes the adjustment of two angles of demand and supply.

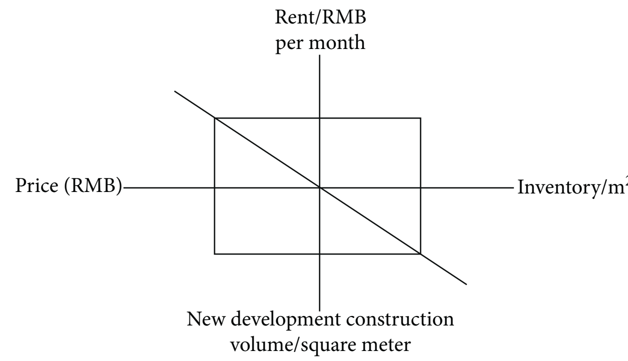

Figure 1: Four-quadrant pattern diagram.

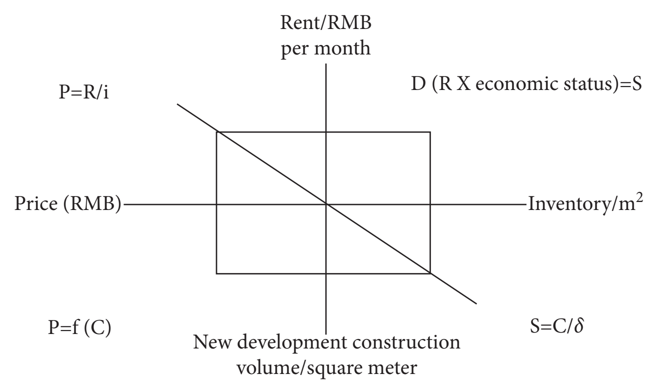

Figure 2: Four-quadrant pattern diagram.

3.1. From the Perspective of Control Requirements. First of all, the state and the government have issued a number of policies to conduct investment and trading rules and carried through a series of measures to conduct speculation in real estate and noninvestment demand. Through the corresponding ant colony algorithm and through the real estate improvement of loan and tax and the corresponding policy changes, the demand for real estate investment income has been improved. As shown in Figure 3, the improvement of different capitalization rates can bring about the corresponding equilibrium changes. When the expected development and construction amount is reduced, the property stock and rent of the related real property have increased. This is counterbalanced with the new amount of development and construction.

In the long run, the rent of real estate increases and the corresponding capitalization, so as to reduce the real estate price, reduces the development and construction volume of

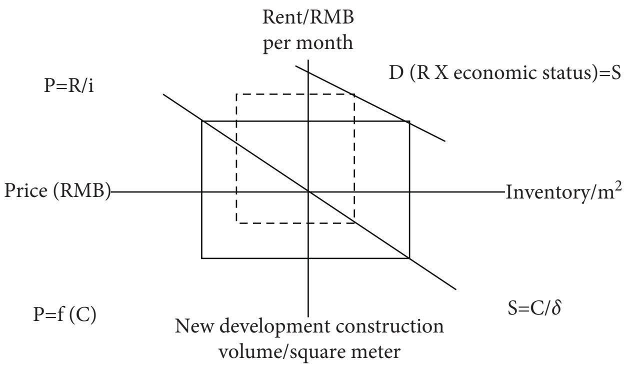

Figure 3: Four-quadrant pattern diagram.

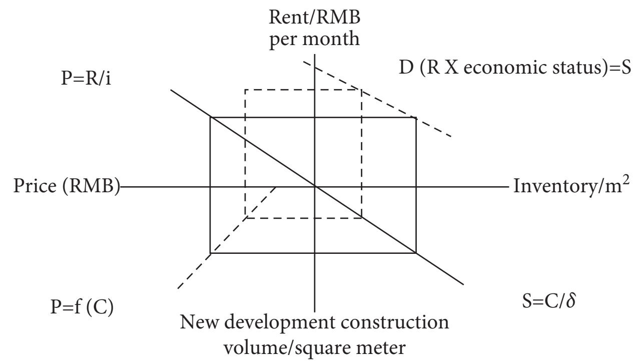

Figure 4: Four-quadrant pattern diagram.

the heart and stabilizes the real estate market. In the short term, the policy can reduce the demand for speculation to a certain extent, but due to the complexity of China's real estate market and the difference in regional development is too large, so the response of adjustment in real estate is too slow.

Equation (2) controls the supply.

From the perspective of supply control, it mainly covers credit, natural resources real estate, tax, etc. In terms of the ant colony algorithm, the land supply of the natural resource real estate, the control of the credit scale, and the real estate cost are reflected in the rays in Figure 4 to ensure that the balance state changes.

In the long run, these controlled supplies are in line with the long-term goal of the long-term control of the stable growth of China's real estate industry. In the short term, the real estate may have the supply ownership, but both the investment demands have been reduced. According to the corresponding theory of supply and demand relationship, the real estate price has been reduced and changed in a certain period of time, which means that the government can effectively control the housing price.

Through the ant group algorithm, in the case of the supply relationship changes to a certain extent, the real estate combining has been retained, and the use demand of real estate can meet different real estate ownership, and the rent will be relatively reduced. If the balance state changes and the demand curve is shifted, the speculative and nonspeculative demand for real estate will be reduced. When equilibrium is reached, the ant colony algorithm overall shrinks, contrary to economic expansion, as shown in Figure 5:

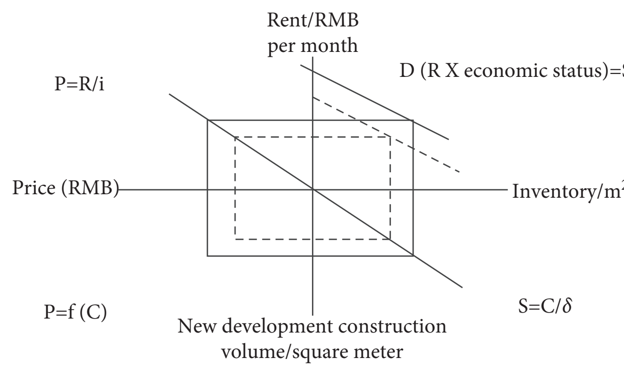

Figure 5: Four-quadrant pattern diagram.

National macrocontrol policies range from control to protection, with the focus on supporting residents in solving housing problems.

The contribution rate is the specific monitoring and measurement of the overall impact of a certain index on the economy:

$$\mathrm{Con}_{\mathrm{it}} = \frac{\Delta \mathrm{Val}_{\mathrm{it}}}{\Delta \mathrm{GDP}_t} \times 100\%. \tag{3}$$

From the calculation results, from 2018 to 2020, the contribution rate of the primary industry was on the rise, the contribution rate of the secondary industry was decreased, and the contribution rate of the tertiary industry showed a steady rise.

From the results in Figure 6, if the secondary industry declines, from the perspective of real estate alone, the economic contribution rate of real estate is basically about 7%, but there is still a big gap compared with the contribution of industrial economy to China's economic growth.

4. Simulation Experiment and Analysis

4.1. Analysis Based on State Space Models. State space models are a powerful tool for the dynamic analysis of interrelations between variables. The model uses a powerful iterative algorithm called the Kalman filter to incorporate unobservable variables into the observable model and obtains estimates with it:

$$\begin{aligned}
&\begin{cases} \log\left(\mathrm{GDP}_t\right) = \alpha_t + \beta_t \log\left(\mathrm{industry}_t\right) \times + \widehat{u} \\ \beta_t = a + b \times \beta_{t-1} + \widehat{\varepsilon}_t \end{cases}, \quad t = 1, 2, \ldots, T, \\
&\begin{cases} \log\left(GDP_t\right) = \alpha_t' + \beta_t' \log\left(\mathrm{realestate}_t\right) \times + \widehat{u}\,' \\ \beta_t' = a' + b' \times \beta_{t-1}' + \widehat{\varepsilon}_t' \end{cases}, \quad t = 1, 2, \ldots, T.
\end{aligned} \tag{4}$$

Using the data provided by the China Statistical Yearbook 2020, the changes in the parameters β_t and β_t' of the sample period can be obtained, as shown in Figure 7. The

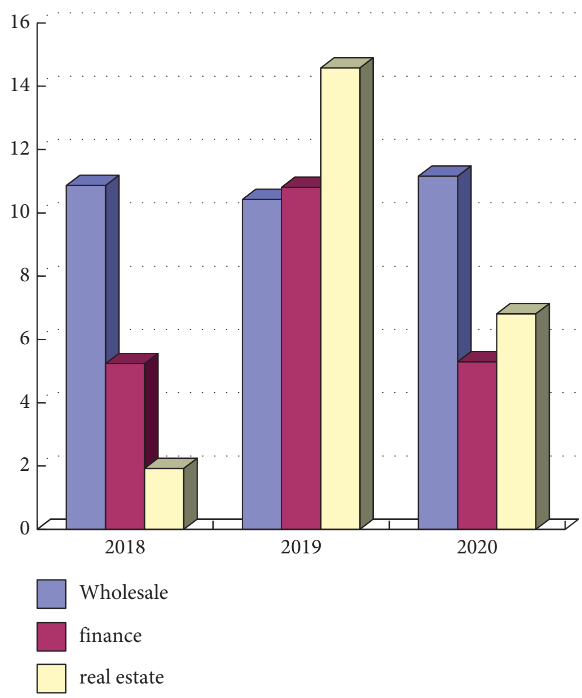

Figure 6: Industry contribution unit (%) from 2018 to 2020.

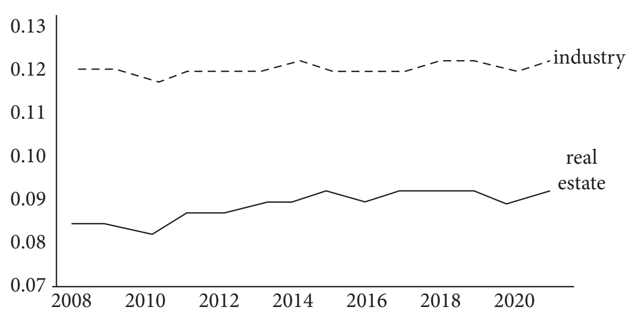

Figure 7: Parameter changes of the state space model from 2002 to 2015.

elasticity of GDP to industry is relatively stable, fluctuating around 0.12, while in the same period, although the elasticity of GDP to real estate shows the upward trend, the tertiary industry represented by real estate cannot yet replace the position of the secondary industry.

4.2. To Absorb Employment. From the perspective of urban employment personnel, among the 20 industries of China's national economy, the person directly engaged in real estate accounts for not much, only accounting for about 2%.The top three industries are manufacturing, construction, and education, accounting for 27.7%, 15.3%, and 9.5%, respectively, 12.1 times, 6.7 times, and 4.1 times the number of real estate practitioners, respectively (Figure 8).

As a capital company, the capital party, its purpose is to obtain operating profit. In the general concept, the real estate development is good, its operating profit is relatively high,

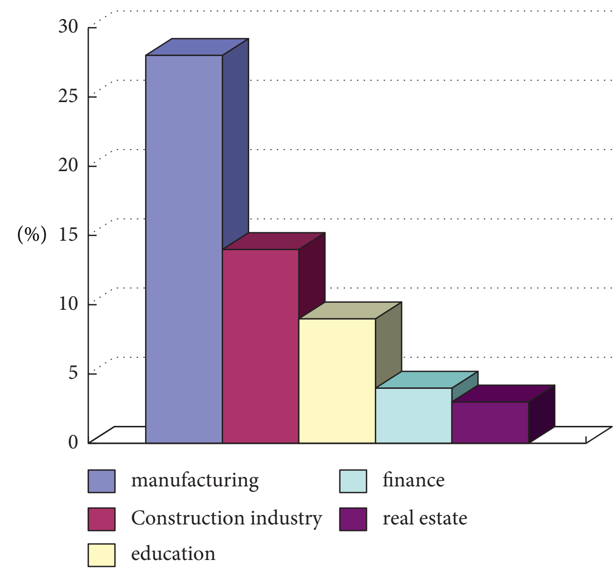

Figure 8: Employment of urban units in some industries accounted for units (%) in 2020.

the real estate development is not good, and its operating profit is relatively low. Although China's real estate market has basically maintained a bull market for more than ten years, the real estate industry profit should be a lot.

As a capitalist real estate company, the purpose of its operation is to obtain operating profits. In the general concept, if real estate develops well, its operating profit is relatively high. If real estate develops well, its operating profit is relatively low. China's real estate market has basically maintained a dozen or so despite occasional fluctuations. In the bull market of 2015, the real estate industry should have made a lot of profits.

According to China's current division of powers and financial powers, local governments undertake a large number of tasks, but financial powers are concentrated in higher-level governments, making local governments have to regard real estate as the "second fiscal" in order to complete economic and social development tasks. Real estate has a huge impact on local finances. To resolve the dependence of local governments on real estate development, it is necessary to solve the dependence of local finance on real estate development. Only by liberating local finance from land gains can the local government's benign guiding role in real estate development be fundamentally given play to. Reform the existing fiscal and taxation system and reasonably divide central and local affairs so that local governments have sufficient financial resources to effectively handle their affairs without relying on land and provide guarantees for local economic development, people's lives, and social stability.

The issue of human capital has always been a key area of economic research. In the history of economic research, Malthus' theory of population disasters has appeared, and the important role of human capital in economic growth has also been strongly promoted. Despite the school disputes, it is undeniable that human capital is an important factor in a country's economic growth. Empirical evidence shows that there is a close correlation between population growth and economic growth. The recession of the Japanese economy, the stagnation of the European economy, the arrival of an aging society, and the negative growth of the population appeared. As the world's most populous country, China's most basic resource is human capital. In 1978, China implemented reform and opening up. The low labor cost is one of the important reasons why the economy can develop in great strides. In addition to the large population, another important reason for the low labor cost in China is that China's family planning policy started in the last century has caused the dependency ratio to drop drastically and enjoy a huge demographic dividend. However, the current population aging in China is very fast. In 2015, the number of people over 60 years old in China exceeded 200 million, accounting for 16.1%, and the number of people over 65 years old has reached 140 million, accounting for 10.5%. According to the aging society standard that the population over 60 years old accounted for more than 10% and the population over 65 years old accounted for more than 7%, China has actually entered an aging society, and the aging degree will be further increased in recent decades. The heavier burden and the decline in the proportion of the right-age labor force have greatly increased the average cost of labor in our country and have brought tremendous pressure to the normal operation of enterprises and the normal operation of individual families. For China, maintaining the sustainable development of the economy and society is still the biggest task in the future period of history. It is recommended to further adjust the family planning policy to promote the moderate growth of the population and continue to maintain the competitiveness of China's enterprises and the sustainable development of the family.

The tax burden of economic units in China is relatively heavy. The measurement caliber of the macrotax burden has three categories: narrow caliber, medium caliber, and wide caliber. The narrow caliber refers to the proportion of tax revenue in GDP, the medium caliber refers to the proportion of fiscal revenue in GDP, and the wide caliber refers to the proportion of revenue that all governments can control or influence in GDP. China's narrow-caliber macrotax burden is less than 20%, the medium-caliber macrotax burden is slightly higher than 20%, and the wide-caliber macrotax burden is close to 40%. From the perspective of the relationship between households, enterprises, and the country and the development of households and enterprises, a wide-caliber macrotax burden is more reasonable. At present, China's wide-caliber macrotax burden has been much higher than the average level of developing countries and even higher than the level of some developed countries. The burden of taxes and fees makes the economic unit's operating results unable to be used for technological innovation and self-development, and the development of competitiveness is greatly affected. For China's sustainable development, tax cuts are an important way to mobilize the enthusiasm of households and enterprises and stimulate their creativity. In the future, necessary explorations should be made in tax cuts, especially structural tax cuts.

Science and technology are primary productive forces. Since the reform and opening up, China has gradually increased its investment in science and technology research and development, and the progress in science and technology has made rapid progress, which has promoted the rapid development of China's economy and has become the world's second largest economy. However, despite the rapid progress in science and technology in China, the gap with developed countries is still huge. The intuitive manifestation of the relatively weak technological innovation ability is the low added value of technology made in China. Technology is the main source of the added value of high-tech products, and the price of commodities is the most important competitiveness of non-high-tech products, but the price factor is greatly affected by the cost. In the context of reduced labor, higher tax costs, and rising raw material prices, the competitiveness of China's low value-added products has dropped significantly. In the future, we should optimize the technological innovation environment, increase investment in science and technology, improve China's technological innovation capabilities, especially the technological innovation capabilities of enterprises, and then increase the technological added value of Chinese products so that the advantages of Chinese products will be transformed from low prices to advanced technology.

5. Conclusions

With the continuous development of social economy, urban real estate has an influence on the macroeconomy, and how to trace its external influence factors is very important. In view of these limitations and needs, this paper is based on ant algorithm, by combining the operation of the real estate market to adjust the real estate market, using national policy impact analysis, explore the national policy on real estate, to effectively adjust the policy, using the "four-quadrant" model to analyze the impact of the real estate market, further promote the healthy development of real estate, and realize the effective development of national economy. Simulation experiments have proved that the ant colony algorithm is effective.

Data Availability

The labeled dataset used to support the findings of this study is available upon request to the author.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Research on the Evolution of High-Quality Development of China's Provincial Foreign Trade

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The new development concept is the theoretical guidance and important foundation for high-quality foreign trade development in the new era. This paper develops an evaluation index system to measure the high-quality development level of foreign trade based on the meaning of high-quality development of foreign trade under the new concept of development. The dynamic changing trend of high-quality development of China's provincial foreign trade from 2013 to 2019 and the ranking change of the development index are examined in this paper using a time series factor model. Finally, China's provinces are categorized based on the quality of their foreign trade development. The findings show that, from 2013 to 2019, China's high-quality foreign trade development has been on the rise; the level of high-quality foreign trade development has been raised to varying degrees in the eastern, central, and western regions of China, but each region plays a different role. Compared to 2013, the truly "high-quality" areas of China's provincial foreign trade development were always concentrated in the eastern region, which ranked high on the comprehensive evaluation index, while the "low-quality" areas were mainly concentrated in the central and western regions, which ranked low on the comprehensive evaluation index.

1. Introduction

China has made remarkable achievements in foreign trade over the course of more than 40 years of reform and opening-up and has risen to become the world's first trade power. China's foreign trade has successfully completed the "Quantity" leap while also greatly improving in "Quality," with the trade structure continuing to improve and trade competitiveness improving. However, China's foreign trade development is beset by difficulties. The new crown epidemic, in particular, continues to spread around the globe, and the external environment is becoming more uncertain and risky. The global economy remains sluggish in the face of profound changes unseen in centuries, making China's foreign trade situation more complex and severe, with numerous flaws. The promotion of high-quality foreign trade development has become a central issue in China's trade development. The 19th CPC National Congress pointed out that China's economy will develop from high speed to high quality. It requires that China's trade development change from high-growth to high-quality stage. In 2019, the CPC Central Committee and the State Council issued "the Guiding Opinions on Promoting High-quality Development of Trade," which further points out the direction for China's high-quality development of foreign trade in the new era and at the same time puts forward new requirements. Therefore, to scientifically build an evaluation system for the high-quality development of China's foreign trade, to measure the high-quality development of China's foreign trade in the new era, and to find out the sources of power and sources of resistance, it is of far-reaching practical significance to promote the high-quality development level of China's foreign trade.

So, has China's foreign trade's high-quality development level improved? What about China's provincial foreign trade's high-quality development level? What distinctions, trends, and gaps exist between regions? As a result, the paper develops a high-quality development index system for China's provincial foreign trade and employs the global factor model of time series to measure and analyze the high-quality development level of China's provincial foreign trade. This paper examines the advantages and disadvantages, as well as the potentials and barriers, to the development of foreign trade in each province in order to provide a reliable endogenous power source for the high-quality development of China's foreign trade.

At present, scholars' research on the high-quality development of foreign trade mainly focuses on the following aspects:

(1) The meaning of high quality in foreign trade. For example, Xiang and Song believe that "Imbalance" and "Inadequate" represent the new era of China's high-quality foreign trade development and from these two aspects give a specific definition [1]; Chen believes that the high-quality development of foreign trade represents the high-level economic and trade cooperation of "You have me, I have you" and can fully highlight the essential goal and development orientation of Integration [2]; Gao believes that an accurate understanding of the meaning of high-quality trade should not only reflect the inherent requirements of building a strong trading nation but also reflect the trend of the times that trade development conforms to the changes in China's social contradictions [3]; Ma believes that high-quality development of foreign trade should include five fundamentals: an optimized development structure, a more balanced development pattern, a sustained development momentum, a more open development model,, and a more inclusive development concept [4].

(2) The research on the measurement and evaluation of the high-quality development of foreign trade. Due to the high-quality development of foreign trade proposed in a relatively short time, the literature in this area are less.

For example, Qu et al. established the index system of high-quality development of foreign trade from the basis of trade, trade optimization, trade competitiveness status, trade comprehensive services, and international economic and trade rules status of five dimensions, which includes 34 indicators, but they did not use the index system to measure the high-quality development of foreign trade [5]; Tang and Xia set up a high-quality development evaluation index system from the perspective of trade in services, which includes five dimensions (openness and security, structural coordination, sustainable development, innovation drive, and international competitiveness) and 27 indicators, and they also used AHP method to carry out the related analysis [6]; Wu and Zhang selected 26 indicators from five aspects, namely, innovative trade, coordinated trade, green trade, open trade, and shared trade, to construct an indicator system which was based on the new concept of development, and then they used the entropy method to measure the high-quality development of China's foreign trade from 2001 to 2018 [7]; Cao and Lei also selected 17 indicators based on the new concept of development, from six dimensions of effective, innovative, coordinated, sustainable, open, and shared development, using entropy weight method to measure the high-quality development of China's foreign trade from 2006 to 2018 [8].

(3) The ways and countermeasures of high-quality development of foreign trade. Some scholars, such as Yang, Chang, and Li, hold that innovative development is the foundation to promote the high-quality development of foreign trade and to strengthen the trade power [9–11]; scholars such as Rong and Xiang hold that the initiative to expand imports is a mechanism to promote high-quality development and its realization path [12, 13]; however, Scholars such as Zhao, Sheng, Pei, and Liu believe that the "fine brushwork" of creating a "Belt and Road" together can continuously open up the market and reduce the degree of dependence on the European and American markets, which is the only way to the high-quality development of foreign trade [14–16].

By examining the existing literature, we can see that, in recent years, an increasing number of scholars have begun to pay attention to China's high-quality foreign trade development, and the scope of the study has gradually expanded from the definition of high-quality foreign trade development to the establishment and measurement of the indicator system. However, because different scholars have different interpretations of what constitutes high-quality foreign trade development, different measurement indexes are chosen, and different measurement results are obtained. Meanwhile, there is little literature on China's high-quality provincial foreign trade. As a result, this paper's marginal contribution consists of the two following points: (1) In terms of the study's content, scholars are currently focusing on the connotation, current situation, and path countermeasures of high-quality foreign trade development, primarily focusing on qualitative analysis; however, measuring the high-quality development level of China's provincial foreign trade is uncommon. As a result, this paper chooses a scientific and rigorous method to measure the high-quality development level of China's provincial foreign trade under the new concept of development, and the research is more in depth. (2) On the research method, this paper uses the time series global factor analysis method to quantitatively analyze the high-quality development of China's provincial foreign trade and space-time dynamic differences, in order to avoid high correlation of variables and subjective randomness in selecting weights.

2. Establishment of an Indicator System for High-Quality Development of China's Provincial Foreign Trade

In order to investigate the changes in time and space of the high-quality development of China's foreign trade, this paper constructs the evaluation index system of high-quality development of China's provincial foreign trade, which is based on the connotation of the high-quality development of China's foreign trade under the new development theory.

2.1. The Construction of an Evaluation Index System. In the new era, the new development concept is the theoretical guidance for the high-quality development of China's foreign trade. Based on this, the paper describes the evaluation index system of high-quality development of China's provincial foreign trade from five aspects: the innovative development of trade, the coordinated development of trade, the green development of trade, the open development of trade, and the development of trade sharing. On the basis of the index system of high-quality development of China trade constructed by Wu and Zhang [7], this paper makes some additions, revisions, and deletions to the index system, as shown in Table 1.

2.2. Data Sources and Indicators Description. The variables of the indicator system in this paper are partly consulted by reference to the established practices and also partly by the following references: using the method of Xu and Lu, the technical complexity of China's provincial high tech exports is calculated in two steps [17]; drawing on research ideas such as those of John et al., from four aspects of transportation infrastructure, port clearance efficiency, system environment, and E-commerce, eight indicators are selected to measure the level of trade facilitation in China and its provinces [18]. Among them, adopting Shi's approach, transport infrastructure facilitation is measured in terms of road density (i.e., the number of miles per 100 square kilometres) and rail network density (i.e., the number of miles per 100 square kilometres) [19]. Using the methods of Yin and others, the customs clearance efficiency of the port is measured by selecting the efficiency of cargo clearance and the efficiency of personnel clearance [20]; using the methods of Chen and Li and Yao and Yan, China's institutional environment is measured by anticorruption efforts and the level of intellectual property protection [21, 22]. The basic data in this paper are from the Statistical Yearbook published by the provinces and regions, "National Economic and Social Development of a Statistical Bulletin," "China Statistical Yearbook on Science and Technology," "China Statistics Yearbook on Environment," "China's Ports-of-Entry Yearbook," the Provincial General Administration of Customs website, provincial statistics department website, and government website. Among them, Tibet is rejected because of too much missing data.

3. The Measurement of the High-Quality Development Level of China's Provincial Foreign Trade Based on the Time Series Global Factor Analysis

(1) Construction of global factor model of time series.

The time series global data sheet assumes that there are n regions as samples for high-quality development of foreign trade, and each sample has m index variables, thus forming a matrix of $n * m$ order with a time span of t years; a global data table A $(n * m * T)$ is constructed:

$$A = \{X_t, \quad t = 1, 2, \ldots T\}. \tag{1}$$

(2) Dimensionless treatment of evaluation index and calculation of correlation coefficient matrix.

(3) Computing covariance matrix.

Define the center of gravity of the global datasheet as follows:

$$\begin{aligned} Z &= \left(X_1, X_2, \ldots, X_m\right) \\ &= \sum_{t=1}^{T}\sum_{i=1}^{n} P_i^t Q_i^t. \end{aligned} \tag{2}$$

P_i^t represents the weight of individual Q_i of the sample in year t and satisfies

$$\sum_{t=1}^{T}\sum_{i=1}^{n} P_i^t = 1, \sum_{i=1}^{n} P_i^t = \frac{1}{T}. \tag{3}$$

Suppose that the overall variables for the measurement of the high-quality development of China's provincial foreign trade are X_j.

$X_j = (X_{1j}^1, X_{2j}^1, \ldots X_{nj}^1; X_{1j}^2, X_{2j}^2, \ldots, X_{nj}^2; X_{1j}^T, \quad X_{2j}^T, \ldots, X_{nj}^T)$.

Then the global variance function is $E_j^2 = \mathrm{var}(X_j) = \sum_{t=1}^{T}\sum_{i=1}^{n} P_i^t (X_{Xj}^t - \overline{X}_j)^2$.

The corresponding global covariance function is

$$\begin{aligned} E_{jk} &= \mathrm{cov}\left(X_j, X_k\right) \\ &= \sum_{t=1}^{T}\sum_{i=1}^{n} P_i^t\left(X_{Xj}^t - \overline{X}_j\right)\left(X_{jk}^t - \overline{X}_k\right). \end{aligned} \tag{4}$$

Thus, the global covariance matrix can be expressed as $V = \sum_{t=1}^{T}\sum_{i=1}^{n} P_i^t (Q_i^t - Z)(Q_i^t - Z)'$.

(4) Find the eigenvector of the covariance matrix

(5) Calculate common factors

When the global factor method is used to analyze the time series, the main steps to determine the weight of the index variables are as follows.

Step 1. Itis to find the expression of the global common factor as follows:

Table 1: Evaluation index system of high-quality development of China's provincial foreign trade.

Criterion	Indicator	Variable
Innovative development of trade	Innovation investment	Input intensity of R&D (+) Input intensity of education (+) Quantity of R&D personnel (+)
	Innovation output	TC index of trade in goods (+) TC index of trade in services (+) Processing trade's value-added rate (+) Export technical complexity of high-tech industry (+)
Coordinated development of trade	Structure of trade mode	Export share of general trade (+) Import share of general trade (+)
	Structure of trade entity	Proportion of foreign-capital enterprises in trade (+) Proportion of private enterprises in trade (+)
Green development of trade	Environmental effect	Emission intensity of export industrial waste gas (−) Emission intensity of export industrial waste water (−) Emission intensity of export industrial solid waste (−)
	Resource utilization	Resource consumption per unit export value (−) Proportion of imports of resource products (+)
Open development of trade	Dependence on foreign trade	Total volume of trade/GDP (+)
	Market structure of foreign country	Export market evenness (+) Import market evenness (+) Export market dispersion (+) Import market dispersion (+)
	Trade facilitation	Transport infrastructure (+) Port clearance efficiency (+) Institutional environment (+) E-commerce (+)
Sharing development of trade	Per capita foreign trade volume	Total volume of trade/total population (+)
	Contribution of trade to the economy	Net export growth/net GDP growth (+)
	Contribution of trade to employment	Total employment × total volume of export/GDP (+)

$$\begin{aligned} G_1 &= U_{11}X_1 + U_{21}X_2 + \cdots + U_{n1}X_n, \\ G_m &= U_{11}X_1 + U_{21}X_2 + \cdots + U_{nm}X_n. \end{aligned} \tag{5}$$

Among them, G_m is the global common factor m, X_n is the observation variable n, and U_{nm} is the score coefficient of the observation variable n in the global common factor m. After dimension reduction by factor analysis, it should be l $m < n$ in general.

Step 2. Itis to construct the expression of comprehensive evaluation score and calculate the index weight.

$$\begin{aligned} ZG &= \frac{(\theta_1 * G_1 + \theta_2 * G_2 + \cdots + \theta_m * G_m)}{(\theta_1 + \theta_2 + \cdots + \theta_m)} \\ &= \pi_{1*}X_1 + \pi_{2*}X_2 + \cdots + \pi_{n*}X_n. \end{aligned} \tag{6}$$

In the above equation, ZG is the comprehensive evaluation score of high-quality development of foreign trade and θ_m is the contribution rate of variance of the global factor m; $\pi_n = (\theta_1 * U_{n1} + \theta_2 * \quad U_{n2} + \cdots + \theta_m * U_{nm})/\ (\theta_1 + \theta_2 + \cdots + \theta_m)$.

Calculate the weight of indicator X_i: $V_i = |\pi_i|/(|\pi_1| + |\pi_2| + \cdots + |\pi_n|)$.

(1) Steps for measuring the high-quality development level of China's provincial foreign trade.

(i) The standardization treatment of single index
Because each index in the original data has a different order of magnitude, the index must first be standardized. Set 2013 as the base year and apply the following rules to the positive and negative indicators:
Positive indicators: Singl Index$J = W_j - W_{\min}/W_{\max} - W_{\min} \times 100$
Negative indicators: Singl Index$J = W_{\max} - W_j/W_{\max} - W_{\min} \times 100$
Among them, W_j is the original data of index j in the base period of a certain region; $W_{\max}$ and $W_{\min}$ are the largest and the smallest of the original values of index j in the base period of 30 provinces, respectively. For other years in each region, a single index is formed relative to the base period.

(ii) Checking the prerequisites
This paper used SPSS 23 software to perform the KMO and Bartlett sphericity tests. The value of KMO in Table 2 is 0.804, which is between 0.8 and 0.9, indicating that the index variable is easy to reduce dimension and is well suited to factor

Table 2: KMO and Bartlett's test.

KMO test	0.874
Bartlett's test of sphericity	df 378 Approx. chi-square 5754.949 Sig. 0.000

analysis. The Bartlett sphericity test has a significance of 0.000, which is less than 0.01 and is appropriate for factor analysis.

(3) The index weight is determined, and the comprehensive score of high-quality development of Chinese provincial foreign trade is calculated.

(i) To extract the global common factors of time series.
In this paper, the global common factor of time series is extracted by the rule that the feature root is greater than 1. As shown in Table 3, four common factors can be extracted, and the cumulative variance contribution is as high as 95%. The gravel map (Figure 1) also shows that selecting 4 common factors is a good fit.

(ii) Calculate the comprehensive index of high-quality development of foreign trade of Chinese provinces.
Firstly, determine the weight of each index; secondly, according to the variance contribution rate and formula of the four global common factors extracted, the comprehensive evaluation expression of high-quality development of China's provincial foreign trade can be obtained. Finally, the weight of 28 indicators can be obtained.

(4) According to the comprehensive index of high-quality development evaluation of Chinese provincial foreign trade, cluster analysis is carried out.

4. The Results of the Measurement of the High-Quality Development Level of China's Provincial Foreign Trade

Based on the global factor analysis model of time series, the measure steps are completed, and the weights of related indexes are obtained, China's provincial foreign trade quality development index from 2013 to 2019 (shown in Table 4).

4.1. The Result of High-Quality Development Evaluation Index of Chinese Provincial Foreign Trade. Table 4 shows the results of the comprehensive index of the high-quality development of China's provincial foreign trade from 2013 to 2019. Through observation and analysis, the results can be summarized as follows.

To begin with, the high-quality development of China's foreign trade as a whole shows a rising trend in fluctuation when compared to the national average. China's foreign trade quality development index climbed from 38.56 in 2013 to 39.99 in 2015 and then dipped in 2016 before rising to a new high of 40.81 in 2019. This clearly shows that China's high-quality foreign trade development has yielded phased results, effectively promoting the reform of foreign trade power and efficiency. In terms of rate of increase, China's composite index of high-quality development of foreign trade has risen by 2.25 in seven years, especially since 2017, reaching a new high, indicating that it has effectively promoted structural adjustment of China's foreign trade and a change in trade growth pattern in the context of high-quality development.

Secondly, from the perspective of the comprehensive evaluation index of high-quality development of China's provincial foreign trade, there is an obvious upward trend of fluctuations. Against the background of the overall high-quality development of China's foreign trade, the foreign trade development of the vast majority of provinces keeps pace with the high-quality development of China's foreign trade, even faster than that of the country, but, at the same time, the high-quality development index of foreign trade of some provinces appears to regress. This just shows that the high-quality development of China's foreign trade is not plain sailing, the growth rate of foreign trade in some provinces is facing the shift period, the period of painful adjustment of foreign trade structure, and the period of digesting the national foreign trade stimulation policy. The high-quality development of China's foreign trade not only has to face the uncertainty of the external environment but also has to bear the huge pressure of the "three-phase superimposition" in the internal regions. Therefore, in order to successfully pass the road of high-quality development of foreign trade and finally realize the trade power, it requires the coordinated development among the provinces to maintain the stability of high-quality foreign trade and finally to ensure the long-term power of the provincial government's high-quality foreign trade development and construction.

Finally, the high-quality development index of China's provincial foreign trade reveals the characteristics of regional imbalance based on the three regional averages. According to the average of China's three regional high-quality foreign trade development indexes, high-quality foreign trade development in each region has increased to varying degrees between 2013 and 2019, but there is a significant gap between regions. During the reporting period, the average value of the comprehensive index of high-quality development of foreign trade in the eastern region was always higher than the national average, indicating that it was the "leader" of China's high-quality development of foreign trade, while the average value of the central region was essentially the same as the national average, indicating that China's foreign trade is a high-quality development of the "Runner"; the western region has been lower during this period. Furthermore, it is easy to see the "high-quality" provinces in China's real foreign trade, which are primarily concentrated in the east, and the "low-quality" provinces in the Midwestern Sectional Figure Skating Championships.

4.2. The Analysis of the Ranking and Changes. According to the comprehensive evaluation index of high-quality

Table 3: Total variance explained.

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	20.761	74.145	74.145	20.761	74.145	74.145
2	3.294	11.763	85.908	3.294	11.763	85.908
3	1.552	5.543	91.451	1.552	5.543	91.451
4	1.001	3.576	95.028	1.001	3.576	95.028
5	0.386	1.379	96.407			

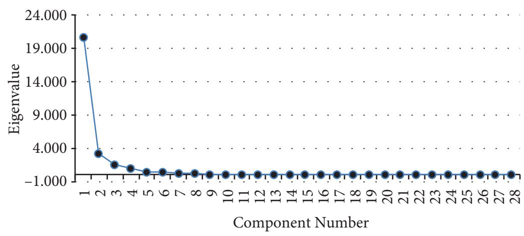

Figure 1: Scree plot.

development of China's provincial foreign trade from 2013 to 2019, the provincial ranking and changes are shown in Table 5.

Judging from the ranking of the comprehensive evaluation index of high-quality development of provincial foreign trade, in 2013, Beijing, Guangdong, Shanghai, Zhejiang, Jiangsu, Shandong, Anhui, Fujian, Tianjin, and Chongqing ranked in the top 10 on the comprehensive evaluation index for high-quality development of provincial foreign trade, with 8 of the top 10 in the eastern provinces, and the central and western provinces each had one; Hubei, Jiangxi, Guizhou, Shanxi, Liaoning, Jilin, Henan, Ningxia, Heilongjiang, and Gansu were ranked 11th to 20th, respectively, including one eastern province, six central provinces, and three western provinces; Hunan, Yunnan, Sichuan, Guangxi, Shaanxi, Hainan, Inner Mongolia, Qinghai, Hebei, and Xinjiang are ranked 21th–30th, and these ten provinces were three in the east, two in the centre, and five in the west. Based on this, it can be concluded that, in 2013, the provinces with the higher comprehensive evaluation index of high-quality development of foreign trade in China's provinces were mainly concentrated in the eastern region, while the middle-level provinces were concentrated in the central region, and half of the provinces in the west ranked relatively low. In 2019, Beijing, Guangdong, Shanghai, Zhejiang, Jiangsu, Fujian, Shandong, Chongqing, Anhui, and Guizhou were the top 10 ranked in China's foreign trade quality comprehensive evaluation index: seven eastern provinces, one central province, and two western provinces; Jiangxi, Tianjin, Hubei, Hunan, Jilin, Ningxia, Henan, Liaoning, Gansu, and Shaanxi were ranked 11th–20th, followed by Jiangxi, Tianjin, Hubei, Hunan, Jilin, Henan, Gansu, and Shaanxi: two eastern provinces, five central provinces, and three western provinces; Hebei , Heilongjiang, Yunnan, Shanxi, Inner Mongolia, Sichuan, Guangxi, Xinjiang, Hainan, and Qinghai were ranked 21st to 30th: three of the 10 provinces were in the east, three in the centre, and four in the west. Compared with 2013, in 2019, the provinces with higher comprehensive evaluation indexes for high-quality development of foreign trade in China's provinces were still concentrated in the eastern region, while the provinces with lower comprehensive evaluation indexes were still concentrated in the central and western regions; the phenomenon of "east high, middle high and west low" still existed.

From 2013 to 2019, the rankings of 12 provinces rose, accounting for 40% of the total: two provinces in eastern Hebei and Fujian, four provinces in central Inner Mongolia, Jilin, Jiangxi, and Hunan, and six provinces in the west: Chongqing, Guizhou, Shaanxi, Gansu, Ningxia, and Xinjiang. Hebei, Hunan, and Shaanxi all saw higher increases, with Hebei up 8, Hunan up 7, and Shaanxi up 5. Six provinces remained unchanged in the rankings during the same time period: Beijing, Guangdong, Shanghai, Zhejiang, Jiangsu, and Henan. The other 12 provinces fell during the same time period, with five in the eastern provinces of Tianjin, Liaoning, Shandong, Guangxi, and Hainan; four in the central provinces of Shanxi, Heilongjiang, Anhui, and Hubei; and three in the western provinces of Sichuan, Yunnan, and Qinghai, respectively.

4.3. The Cluster Analysis of the High-Quality Development of China's Provincial Foreign Trade. According to the comprehensive index of the high-quality development of China's provincial foreign trade shown in Table 4, based on the cluster analysis, 30 provinces are divided into 4 categories.

The first category includes Beijing, Guangdong, and Shanghai. These three cities are the regions where the foreign trade is developing with the highest quality, and their comprehensive index of high-quality development of foreign trade has maintained the top three places in the ranking from 2013 to 2019. The overall development of high-quality development of foreign trade is on a steady upward trend; it will play an important leading role in the high-quality development of foreign trade in other regions of China. Beijing, Shanghai, and Guangdong are China's economically powerful cities with convenient transportation and high level of infrastructure construction. No matter capital or talents, these three cities will be considered or selected optimally. All aspects are conducive to the development of their foreign trade. Guangdong, as a big and powerful trade city of China, has unique geographical conditions, is the window of China's opening up, and is the barometer of China's foreign trade. For Beijing and Shanghai, two international metropolises, all aspects of development follow the pace of the world, so they also have strength and advantages in high-quality development of foreign trade,

Table 4: 2013–2019 China's provincial foreign trade quality development index.

		2013	2014	2015	2016	2017	2018	2019
Eastern region	Beijing	55.48	56.29	58.31	58.39	57.43	60.26	60.41
	Shanghai	52.60	53.38	54.95	54.90	55.91	54.98	55.32
	Tianjin	40.78	41.24	41.55	39.9	39.39	38.51	40.96
	Hebei	29.37	34.24	35.08	31.32	34.29	35.22	36.11
	Liaoning	36.97	36.39	36.23	33.12	35.62	37.48	38.26
	Jiangsu	45.30	46.59	45.77	48.10	46.35	48.48	48.33
	Zhejiang	46.28	44.93	47.57	46.86	47.66	46.68	49.11
	Fujian	41.75	42.25	44.89	42.59	48.22	46.73	46.06
	Shandong	44.56	44.10	44.30	43.60	43.48	44.45	44.86
	Guangdong	55.56	56.64	56.68	57.64	58.63	59.25	61.06
	Hainan	32.72	30.22	35.41	29.71	29.04	30.03	31.9
	Average	43.76	44.21	45.52	44.19	45.09	45.64	46.58
Central region	Jilin	35.88	38.71	38.03	35.46	37.60	40.52	40.18
	Heilongjiang	36.74	34.54	38.77	33.23	32.88	36.96	35.83
	Anhui	41.96	43.34	44.07	43.95	42.45	43.57	42.58
	Jiangxi	37.91	37.11	39.24	37.9	38.95	42.77	41.95
	Henan	36.43	35.71	36.65	36.41	37.24	41.42	39.86
	Hubei	38.20	38.47	39.54	40.09	39.88	39.40	40.37
	Hunan	34.47	36.10	35.10	38.70	36.62	39.06	40.23
	Shanxi	37.36	36.24	35.55	34.51	32.04	36.33	34.04
	Average	37.37	37.53	38.37	37.53	37.21	40.00	39.38
Western region	Guangxi	33.20	30.71	32.27	30.18	31.11	31.86	32.39
	Chongqing	38.77	37.51	41.89	41.62	42.59	43.05	43.50
	Sichuan	37.45	32.20	36.91	30.95	31.65	32.97	32.70
	Guizhou	37.65	37.28	41.06	39.25	36.88	36.99	42.32
	Yunnan	34.46	34.65	35.70	34.21	35.58	36.72	34.85
	Shanxi	32.81	32.43	33.38	34.13	35.10	35.70	36.66
	Gansu	35.20	35.86	39.28	33.99	39.19	38.75	36.9
	Qinghai	30.40	37.71	31.51	27.81	36.13	32.61	31.47
	Ningxia	35.26	38.72	34.84	37.40	41.72	42.50	40.11
	Xijiang	29.12	34.35	32.45	30.81	32.19	33.22	32.11
	Average	34.04	35.40	35.64	33.57	36.06	36.18	35.89
	Average of China	38.56	39.11	39.99	38.54	39.58	40.75	40.81

becomeing the leader of high-quality development of China's foreign trade.

The second category includes Jiangsu, Zhejiang, Anhui, Shandong, and Fujian. These provinces, except Anhui, are all eastern coastal provinces, all of which have good geographical conditions, strong base, and sufficient reserves of capital and talents, and have been playing an important role in the development of China's foreign trade. In the context of China's high-quality development, these provinces have followed in the footsteps of the country, promoted the position of foreign trade in the international value chain through transformation and upgrading, and strengthened their ties with other provinces within China; enhancing their own foreign trade development capacity at the same time also led to the development of foreign trade in other provinces. In terms of geographical location, these provinces are characterized by the encirclement of Jiangsu, Anhui, and Fujian, which encircles Zhejiang in the middle, and the border of Zhejiang, Jiangsu, and Anhui with Shanghai, an international metropolis, although Shandong is not in the first two areas, but with Jiangsu border. Therefore, it can be said that these five provinces are in a good environment, with their own strength, good geographical environment, resource environment, and foreign trade environment in the high-quality development of China's foreign trade, and must become the main force.

Tianjin, Jilin, Jiangxi, Henan, Hubei, Hunan, Chongqing, Guizhou, Gansu, and Qinghai are the ten provinces (or cities) in the third category. Five of the ten provinces are in the central region, four are in the western region, and only Tianjin is in the east. Foreign trade has grown rapidly in recent years in the five provinces of the central region. Jiangxi, Henan, Hubei, and Hunan provinces, in particular, have played a significant role in China's "Rise of the Central Region" and are an important base and integrated transportation hub for the country; they have also taken on the important task of transferring manufacturing industry; the growth rate of foreign trade in the four western provinces is faster and stronger than that in the central region after 2013. However, whether in the central or western regions, these provinces' foreign trade development is still based on the extensive development model. "Three high and one low" will become the biggest obstacle to the future development of the eastern region's trade in the process of developing foreign trade or undertaking industrial transfer.

The fourth category includes the 12 provinces of Hebei, Shanxi, Inner Mongolia, Liaoning, Heilongjiang, Guangxi, Hainan, Sichuan, Yunnan, Shaanxi, Ningxia, and Xinjiang.

Table 5: Ranking and changes of China provincial foreign trade quality development index.

	2013	2014	2015	2016	2017	2018	2019
Beijing	1	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Tianjin	9	9 (0)	10 (−1)	11 (1)	12 (−1)	17 (−5)	12 (5)
Hebei	29	25 (4)	24 (1)	24 (0)	23 (1)	25 (−2)	21 (4)
Shanxi	14	17 (−3)	22 (−5)	18 (4)	26 (−8)	22 (4)	24 (−2)
Neimenggu	27	21 (6)	27 (−6)	29 (−2)	27 (2)	23 (4)	25 (−2)
Liaoning	15	16 (−1)	19 (−3)	23 (−4)	20 (3)	18 (2)	18 (0)
Jilin	16	10 (6)	15 (−5)	16 (−1)	15 (1)	13 (2)	15 (−2)
Heilongjiang	19	23 (−4)	20 (3)	22 (−2)	24 (−2)	20 (4)	22 (−2)
Shanghai	3	3 (0)	3 (0)	3 (0)	3 (0)	3 (0)	3 (0)
Jiangsu	5	4 (1)	5 (−1)	4 (1)	6 (−2)	4 (2)	5 (−1)
Zhejiang	4	5 (−1)	4 (1)	5 (−1)	5 (0)	6 (−1)	4 (2)
Anhui	7	7 (0)	8 (−1)	6 (2)	9 (−3)	8 (1)	9 (−1)
Fujian	8	8 (0)	6 (1)	8 (−6)	4 (4)	5 (−1)	6 (−1)
Jiangxi	12	15 (−3)	14 (0)	14 (0)	14 (0)	10 (4)	11 (−1)
Shandong	6	6 (0)	7 (−1)	7 (0)	7 (0)	7 (0)	7 (0)
Henan	17	20 (−3)	18 (2)	15 (3)	16 (−1)	12 (4)	17 (−5)
Hubei	11	11 (0)	12 (−1)	10 (2)	11 (−1)	14 (−3)	13 (1)
Hunan	21	18 (3)	23 (−5)	13 (10)	18 (−5)	15 (3)	14 (1)
Guangdong	2	2 (0)	2 (0)	2 (0)	2 (0)	2 (0)	2 (0)
Guangxi	24	29 (−5)	29 (0)	27 (2)	29 (−2)	29 (0)	27 (2)
Hainan	26	30 (−4)	25 (5)	28 (−3)	30 (−2)	30 (0)	29 (1)
Chongqing	10	12 (−2)	9 (0)	9 (0)	8 (1)	9 (−1)	8 (1)
Sichuan	23	27 (−4)	17 (10)	25 (−8)	28 (−3)	27 (1)	26 (1)
Guizhou	13	14 (−1)	11 (3)	12 (−2)	17 (−5)	19 (−2)	10 (9)
Yunnan	22	22 (0)	21 (1)	19 (2)	21 (−2)	21 (0)	23 (−2)
Shanxi	25	27 (−2)	26 (1)	20 (6)	22 (2)	24 (−2)	20 (4)
Gansu	20	19 (1)	13 (6)	21 (−8)	13 (8)	16 (−3)	19 (−3)
Qinghai	28	28 (0)	30 (−2)	30 (0)	19 (11)	28 (−9)	30 (−2)
Ningxia	18	13 (5)	16 (−3)	17 (−1)	10 (7)	11 (−1)	16 (−5)
Xinjiang	30	24 (6)	28 (−4)	26 (2)	25 (1)	26 (−1)	28 (−2)

From the point of view of the seven provinces in the western region, all of these provinces belong to the regions where the development level of foreign trade in China's provinces is relatively backward, and the foreign trade is developing at a slower pace and mainly exports resource-intensive and labor-intensive products; because of their geographical location, these provinces have a single foreign trade market structure. For example, Inner Mongolia, Yunnan, and Xinjiang provinces mainly trade with neighboring countries, while Sichuan, Shaanxi, and Ningxia mainly trade with the United States; as a result, the development of foreign trade is easily affected by the change of external environment; Liaoning in the eastern region and Heilongjiang in the central region are both old industrial bases in the northeast of China, and their geographical positions are similar, and the developments of foreign trade are similar. Taihang Mountains separate the eastern part of Hebei from the central part of Shanxi. Both provinces are rich in mineral resources. In the course of their development, they are affected by geographical location, resource endowment, and so forth, and the speed of foreign trade development is relatively slow.

5. Conclusions and Recommendations

Based on the connotation of high-quality development of foreign trade, this paper establishes an index system to measure the high-quality development level of foreign trade of Chinese provinces; using panel data of 30 provinces in China from 2013 to 2019, this paper measures the level of high-quality development of foreign trade in China's provinces and analyzes the ranking and changing trend of its comprehensive development index; 30 provinces were classified according to their high-quality development of foreign trade. The results show that, from 2013 to 2019, the high-quality development of China's foreign trade showed an upward trend; the level of high-quality foreign trade development in the eastern, central, and western regions of China has been raised to different degrees, but each region plays a different role in the development of high-quality foreign trade in China: the eastern region is the "leader," the central region is the "accompanying runner," and the western region is the "following runner." Compared with 2003, in 2019, the truly "high-quality" areas of the high-quality development of China's provincial foreign trade are still concentrated in the eastern region, ranking higher in the comprehensive evaluation index, and "low-quality" areas are concentrated in the Midwestern Sectional Figure Skating Championships, ranking lower in the comprehensive evaluation index.

Based on the previous research, this paper attempts to make policy recommendations from the three following points.

To begin with, trade innovation leads to high-quality foreign trade development. By continuously increasing investment in trade innovation, China's high-quality development of foreign trade can only improve the competitiveness of trade innovation output. We should adopt different policies, focus on innovation input, and aim to upgrade innovation output according to the situation of various provinces and different development priorities from the perspective of China's provincial trade innovation development.

Second, to promote high-quality foreign trade development by strengthening the coordinated development of regional foreign trade, the most important part of achieving a more balanced regional structure is optimizing China's provincial trade mode structure and main trade structure, and the optimization of China's provincial trade mode structure and main trade structure is the basic component to achieve this link. We can see from the cluster analysis that different types of provincial regions have different problems and shortcomings when it comes to trade coordination. As a result, each type of provincial region, in accordance with the overall direction of China's trade development and in combination with its own circumstances, can only develop China's trade in a harmonious manner by constantly adjusting and optimizing the trade structure.

Finally, high-level opening-up will help to accelerate the development of high-quality foreign trade. The concept of trade opening-up should be further developed in the new era. Various provinces should correctly understand the meaning of opening-up in the context of their own circumstances and use reasonable methods to promote the development of trade opening-up in order to improve the conditions for the development of China's foreign trade and to expand the external market space of foreign trade in a broader, deeper, and more reasonable direction.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analyzing the Influencing Factors of Economic Fluctuations in the Era of Big Data

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In view of the problems of poor correlation and poor calculation accuracy of the existing factors affecting economic fluctuations, this paper designs a new method for analyzing the factors affecting economic fluctuations based on the characteristics of the era of big data. First, after determining the factors influencing the economic fluctuations in the era of big data, the calculation method of key impact indicators is clarified. Then, the entropy law method is used to assign a weight value to the index, and the set is formed after the index is gathered. Then, the EM algorithm is used to assign the expected value to the data in the set. Finally, the set of influencing factors of the economic fluctuations is taken as input information, and the correlation evaluation model of influencing factors of economic fluctuations is constructed by the Monte Carlo method to complete the analysis of the influencing factors. The experimental results show that the correlation coefficient of influencing factors of economic fluctuations in the era of big data analyzed in this paper is high and the calculation accuracy of influencing factors is high, which proves the feasibility of this method.

1. Introduction

With the further deepening of the reform of the socialist economic system and the continuous improvement of the reform of the socialist market economic system, the means of national macrocontrol have played a more and more important role in the development of the social economy [1, 2]. The reform of China's market economic system has led China's economy into a new stage, and China's economy has begun to have economic cycle fluctuations with the characteristics of a market economy. Western economists have put forward many economic theories and economic models to explain the reasons for the economic cycle fluctuations in various countries under the market economy system [3]. Some economists have tried to monitor, analyze, and predict the fluctuation of the economic cycle since the beginning of the twentieth century. Cyclical fluctuations are only temporary deviations from equilibrium. The interior of the market economy system is very stable, and the power of the market can ensure the rapid recovery of the equilibrium state [4]. Economists at that time advised the administration not to intervene in the cyclical fluctuations of the economy. Because of this, the research on the economic cycle did not attract enough attention from economists at that time.

From a practical point of view, in countries dominated by the market economy, macroeconomic performance has become an important indicator to measure the administrative ability of the authorities. Therefore, the administrative authorities are trying to reduce the fluctuation range of the economic cycle and prolong the expansion stage of the economic cycle through macroeconomic policies, so as to make the economy in low unemployment stable operation under high growth rate and moderate inflation level [5–7]. The emphasis on macroeconomic performance and the enthusiasm to implement macroeconomic policies make the administrative authorities strive to seek the help of economists. At the same time, economists also hope that their research can affect the decision-making of the administrative authorities. This relationship also further stimulates economists' enthusiasm for the research of economic cycle issues. Globalization has provided a huge driving force for the world economy. Capital, labor, technology, natural resources, and markets have been reoptimized and allocated. The economies of various countries are increasingly interconnected and interdependent, and the international division of labor and international exchange has been expanded and deepened. However, due to the different economic systems and political and social environments of countries all over the world, there are constant collisions, competition, and infiltration in the process of economic globalization, which makes the economic situation complex and changeable. In addition, in recent decades, global environmental change, climate change, economic, social, and political emergencies, and other issues are superimposed with economic issues [8, 9].

The analysis of the influencing factors of economic fluctuations is an overall comprehensive and systematic analysis and judgment of the macroeconomy. It is the final judgment of macroeconomic development through the comprehensive sorting of many statistical data, and it is the progress and leap in the understanding of large complex statistical data. It is the supervision and measurement of a series of indicators representing the process and current situation of economic activities, and based on the understanding of the regularity of the process and the monitoring results, it puts forward an alarm for the possible turning points and major changes in economic activities in the future [10]. According to the analysis of the influencing factors of economic fluctuations, it is very important to adjust the effective strategies of economic development in real time. Therefore, relevant studies have analyzed the factors of economic fluctuation under the background of the big data era and achieved some results.

In the current study, relevant scholars analyzed the factors affecting the internal structure of the economy from the static perspective and found that the enterprises' profitability, debt-paying ability, development ability, operation ability, operation scale, industrial-chain added value, and other factors will have an impact on their capital structure [11]. Other scholars analyzed the changes of capital structure in recent years and found through model analysis that the adjustment speed of capital structure target was slow in the process of economic fluctuations. With the development of capital market, financing methods of listed companies will change, and excessive financing phenomenon exists to a certain extent in equity and debt financing [12]. However, in the existing studies, the impact of economic fluctuations without considering the background of the times is systematically analyzed, leading to poor accuracy of index correlation and impact degree calculation.

Therefore, based on the existing literature research, this paper studies the influencing factors of economic fluctuation in the era of big data. By constructing the index system of influencing factors of economic fluctuation, calculating the weight of each index, and predicting the risks in the index of economic fluctuation factors, this paper provides a certain theoretical basis for the analysis of future economic fluctuation. The technical route of this paper is as follows.

(1) After clarifying the index system of influencing factors of economic fluctuations in the era of big data, the calculation methods of key influencing factor indexes are established through different algorithms.

(2) The weight values of different indexes are determined by entropy law.

(3) The clustering algorithm is used to gather the indicators into a set, then the EM algorithm is used to give the expected value of the data in the set, and then the Monte Carlo method is used to construct the correlation evaluation model of the influencing factors of economic fluctuation. The set of influencing factors of economic fluctuation is used as the input of the model to complete the analysis of influencing factors of economic fluctuation in the era of big data.

2. Construction and Analysis of Index System of Influencing Factors of Economic Fluctuation

2.1. Index System of Influencing Factors of Economic Fluctuation. With the advent of the era of big data, the economic industrial chain is becoming more and more complex, and the characteristics of economic cycle fluctuation will be reflected in the data changes of some economic indicators [13–15]. In the economic fluctuation impact index system, according to the time sequence differences of indicators, they are usually divided into leading indicators, consistent indicators, and lagging indicators [16–19]. The leading indicator refers to the indicator that the occurrence time of its cycle turning point is stably ahead of the corresponding turning point of the overall market cycle and changes ahead of the overall market fluctuation in time. The reason it can predict the trend of economic prosperity is that it has a leading causal relationship with economic activities. Consistency index refers to the index whose cycle turning point appears almost simultaneously with the overall turning point of the market, and the fluctuation in time is consistent with the overall economy. Such indicators have two functions: to describe the boom state of the current economic operation. By analyzing the time difference between the consistent index and the leading index, the time of the overall cycle turning point can be estimated from the turning point of the leading index. The process of constructing the index system of influencing factors of economic fluctuations is shown in Figure 1.

According to the previously mentioned analysis, this paper constructs the key index system of influencing factors of economic fluctuations in the big data era according to the current actual situation. The overall indicators are shown in Table 1.

According to the indicators of different sectors determined, it lays a data foundation for the analysis of influencing factors of economic fluctuations under the background of big data era.

Among them, the calculation method of the determined index affects its analysis. Therefore, the calculation method of the index in the previously mentioned determined influencing factor index system will be clarified.

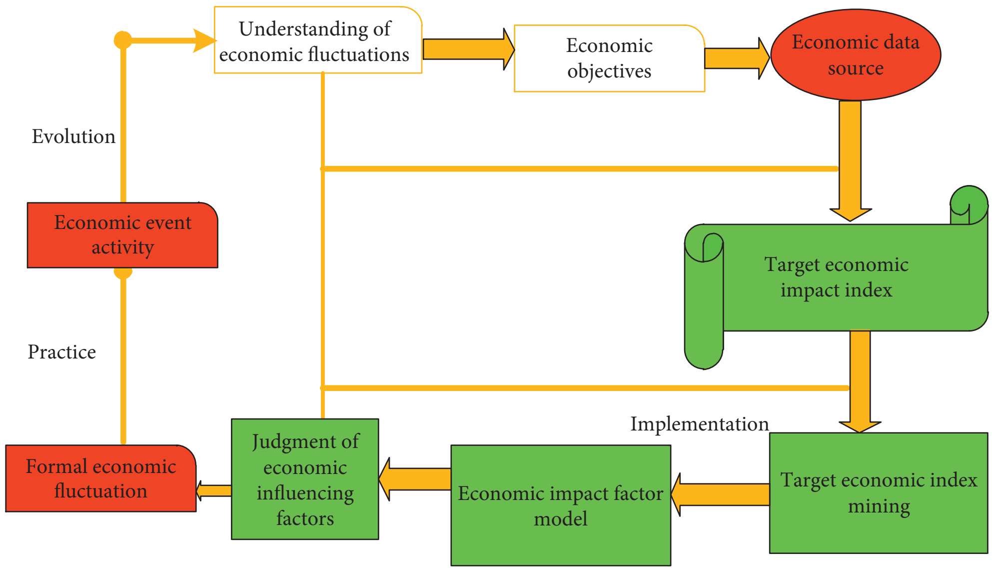

Figure 1: Construction of index system of influencing factors of economic fluctuation.

Table 1: Index system of influencing factors of economic fluctuations in the era of big data.

Level 1 index	Secondary indicators	Detailed
Market economy structure	Economic and industrial structure	Structural balance
	Rationalizing the economic and industrial structure	Market marketization of industrial structure
Economic market system	Economic volatility indicators	GDP and the national economic level
	Economic marketization	Individual economy, collective economy and private economy
Economic policy regulation	Macroeconomic policy	Subjective financial policy
	Microeconomic policy	We will fine-tune economic policies
	External demand	External output and input, etc.

2.2. Index Calculation of Influencing Factors of Economic Fluctuation

2.2.1. Changes in Industrial Structure. The change of industrial structure is the change of the proportion structure of various industries in the national economy, which reflects the adjustment of macroeconomy after the change of internal and external environment, and different industries in the national economy respond differently to the fluctuation of economic cycle. From the perspective of economic dynamic evolution, the change of industrial structure can be measured from the two dimensions of industrial structure rationalization and industrial structure modernization [20–23].

The fluctuation of industrial economic structure affects the fluctuation of the overall economy in the era of big data, which is a key factor that cannot be ignored in social and economic development. Because the structural rationality of different industries needs more factors to be calculated, this paper only focuses on the rationality and irrationality of industrial structure. Since the founding of the People's Republic of China, especially since the reform and opening up, great changes have taken place in China's industrial structure. The proportion of China's three industries in GDP is 15.1%, 45.9%, and 390% in 2019 and 11.3%, 486%, and 401% in 2020. Since then, there has been an upward trend of changes every year. As can be seen from the figure, China's secondary industry is still the leading industry, accounting for the largest proportion, but its proportion has been relatively stable, fluctuating between 41% and 49%. The proportion of the primary industry shows a downward trend year by year, from 28.2% in 2011 to 11.3% in 2020, a decrease of nearly 17 percentage points. The proportion of tertiary industry shows a gradual upward trend, from 23.9% in 2011 to 40.1% in 2020, an increase of 17 percentage points. The overall change trend is shown in Figure 2.

The rationalization of industrial structure also refers to the balance degree of industrial structure, which indicates the reasonable degree of the proportion between various industrial departments in the process of social production, or the balance degree of demand and supply structure of various industrial departments with input–output relationship [24]. This is a key factor in economic fluctuations in the context of big data. Structural deviation degree or structural imbalance degree is generally used to measure [25, 26], and its expression is as follows:

$$R = \sum_{i=1}^{n} \left| \frac{x_i/x_j}{x_i} - 1 \right|. \quad (1)$$

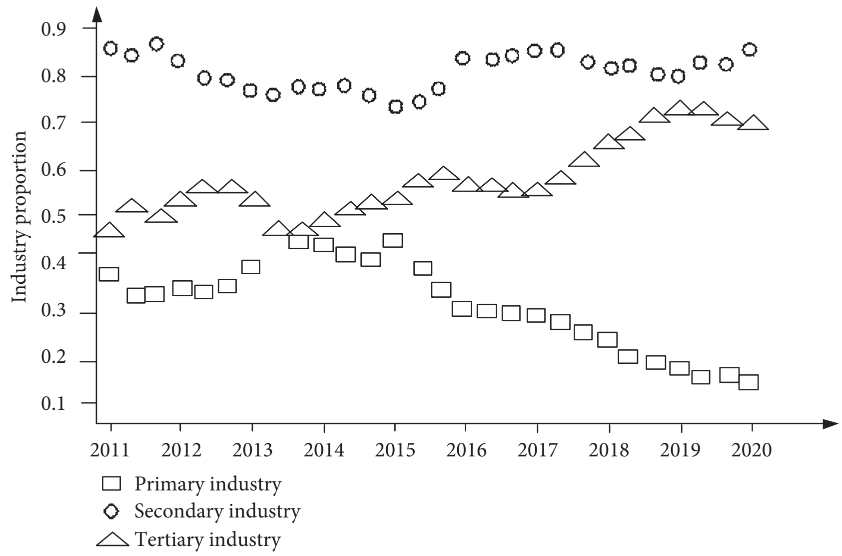

Figure 2: Change trend of proportion of three industries from 2011 to 2020.

Among them, i is the industry category, and $i \in n$, R indicates the imbalance of the industrial structure, x_i is the added value, x_j is the number of employees, and $x_i/x_j/x_i$ indicates the labor productivity.

When $R = 0$, the labor productivity of each industrial sector is just equal to that of the whole economy, and the whole society realizes the optimal allocation of resources. However, in the real economy, this is an ideal state, there is always a structural deviation, and the greater the R value, the more unreasonable the industrial structure [27]. However, this indicator ignores the relative importance of different industries in the national economy. Therefore, in order to reflect this, Theil index is used to measure the deviation degree of industrial structure [28], which is expressed as

$$TR = \sum_{i=1}^{n} \left(\frac{x_i}{x_j}\right) \ln\left(\frac{x_i}{x_j}/x_j\right), \tag{2}$$

where TR represents the imbalance degree of industrial structure.

Formula (2) shows that when the labor productivity of each industrial department is equal to the overall labor productivity, the economy is balanced and the TR is zero. The greater the value of the TR, the more unreasonable the industrial structure.

2.2.2. Calculation of GDP Growth Rate. When studying and analyzing the economic cycle fluctuation, the growth rate of GDP is generally taken as the index to measure the economic fluctuation. However, since the time series data are often nonstationary series data containing trend characteristics, it is necessary to deal with the original data and eliminate the trend components contained in the time series data, and the obtained periodic fluctuation part is taken as the series data of economic fluctuation. In practical application, HP filtering method has strong adaptability, so it is widely used in separating trend components and periodic fluctuations in time series. Therefore, this method is also used in this paper [29].

HP filtering method is based on the principle of symmetrical data moving average method. Its advantage is that it can eliminate the trend components and keep the periodicity of the original data unchanged; that is, the data does not have phase shift [30]. The specific method of HP filtering method is to decompose the time series data into growth trend components and periodic fluctuation components:

$$v_i = a_i + b_j. \tag{3}$$

In the formula, a_i is the trend component and the b_j component of periodic fluctuations. Since the trend component in the time series changes smoothly, it can be obtained by minimizing the following formula:

$$z = \sum_{i=1}^{t} \left(a_i - b_j\right)^2 + \gamma\left[a_{i+} + b\right]_j - \left(a_i - b_j\right)^2, \tag{4}$$

where γ is the smoothing parameter, in a practical application, and the general value is 100.

Due to the rapid rise of GDP, it can be seen from the previously mentioned analysis that when the proportion of the primary industry decreases and the proportion of the secondary industry increases more than the proportion of the primary industry to become the leading industry of the whole economy, the economy has strong volatility; when the proportion of the primary industry and the secondary industry decreases at the same time and the proportion of the tertiary industry continues to rise to a certain extent, the whole economy will show a more stable trend. The change trend is shown in Figure 3.

2.2.3. Economic Policy Indicators. Since the reform and opening up, China's market economic system has been continuously improved, but the government has little influence on the operation of the economy. Control and prediction still have an important impact. The government will use various economic policies to regulate the

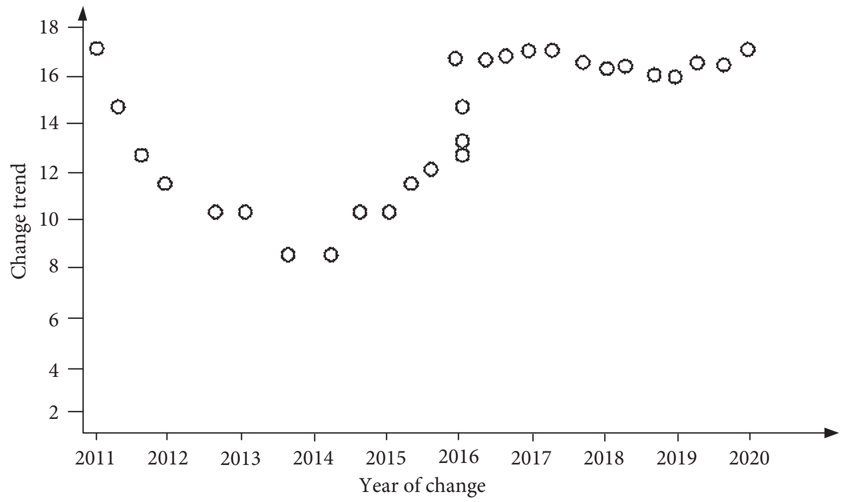

Figure 3: General trend of GDP change in 10 years.

economy, which plays a very important role in the fluctuation of the economic cycle. Among them, fiscal policy and monetary policy are the two most important policy tools for the government to regulate and control economic operation. Fiscal policy is included, and a macroeconomic policy status index, including monetary policy and fiscal policy, is established to measure the tightness of macroeconomic policy [31]. The monetary policy status index is expressed by the weighted average of percentage point changes of interest rate and exchange rate, and its formula is as follows:

$$C = e_i\left(E - E_0\right) + e_j\left(H - H_0\right). \quad (5)$$

Among them, H indicates the actual interest rate, H_0 is the initial interest rate, E indicates the effective exchange rate, E_0 is the initial exchange rate, and e_i and e_j indicate the corresponding weight of the actual interest rate and the effective exchange rate, respectively.

2.2.4. External Demand. Since the reform and opening up, with the expansion and deepening of opening to the outside world, China's trade openness has gradually improved. Foreign demand plays a very important role in China's economy, and the change of foreign demand directly affects the fluctuation of domestic economy. Here, the change of external demand is expressed by the export growth rate:

$$G_t = \frac{p_t}{p_{t-1} - 1} \times 100\%. \quad (6)$$

Among them, p_t represents the total export of the current year; p_{t-1} represents the total export of the previous year.

Opening to the outside world includes the opening of current account and capital account. China's capital account has not been fully opened.

Foreign direct investment (FDI) has been liberalized, but other financial projects are still under control. Here, it is expressed by the growth rate of FDI:

$$F_i = \frac{f_i}{f_{i-1} - 1} \times 100\%. \quad (7)$$

Among them, f_i represents the amount of FDI; f_{i-1} represents the amount of FDI in the previous year.

In recent years, the change trend of external demand indicators is shown in Figure 4.

According to the previously mentioned analysis, the relationship structure between the indicators of influencing factors and economic fluctuations can be determined, which is more complex, as shown in Figure 5.

To sum up, based on the analysis of the characteristics of the big data era, this study constructs the index system of influencing factors of economic fluctuations and defines the calculation method of key influencing factor indicators through different algorithms, so as to lay a foundation for subsequent research.

3. Weight Calculation and Correlation Evaluation of Influencing Factors

3.1. Weight Calculation of Influencing Factors of Economic Fluctuations in the Era of Big Data. There are many datasets in the influencing factors of economic fluctuations in the era of big data, so it is impossible to calculate one by one, which will increase the complexity of the research. Therefore, this paper calculates the weight of the key influencing index factors constructed as previously mentioned. The most commonly used diversification index is entropy index. The concepts and viewpoints related to nature defined in the entropy law, such as equilibrium state, maximum value, and uniform distribution, attract regional researchers to explore the measurement of economic diversity in this regard. Entropy is calculated as follows:

$$K = \sum_{i=1}^{n} q_{ij} \ln \frac{1}{q_{ij}}. \quad (8)$$

Among them, q_{ij} represents industry j employment in the share of total employment. The entropy index increases with

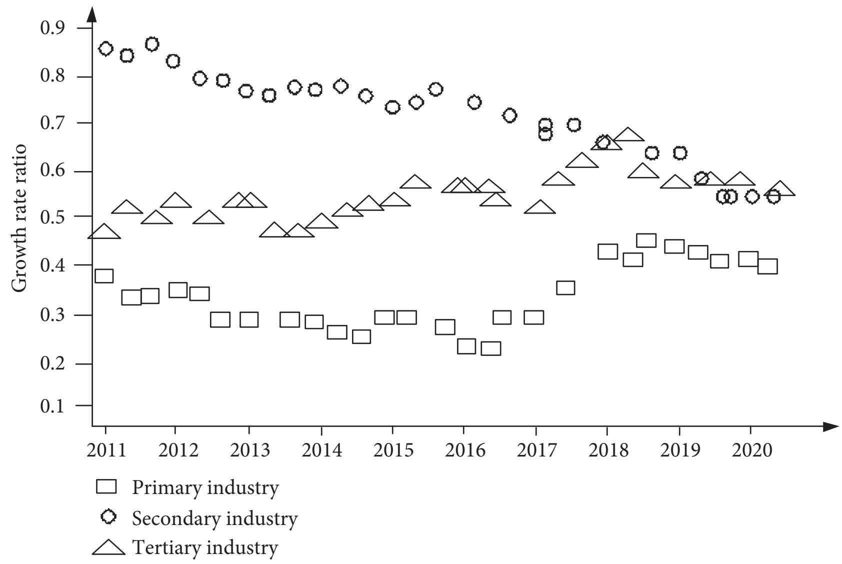

FIGURE 4: Variation trend of external demand indicators.

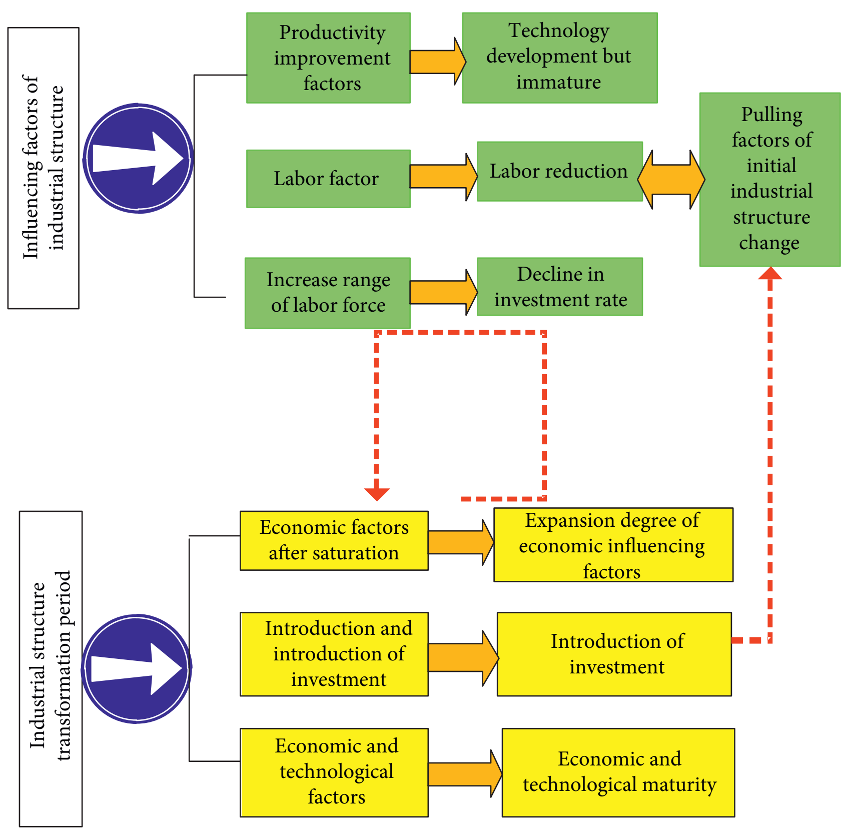

FIGURE 5: Structural diagram of the relationship between influencing factor indicators and economic fluctuations.

the growth of the number of departments in a region and the average of each sector. If the regional economy is completely evenly distributed among N industries, the entropy index reaches the maximum $\ln(1/q_{ij})$, representing complete diversification. Instead, if a region economy is concentrated in a certain industry, $q_{ij} = 1$ and the entropy index value is 0.

The construction of entropy also determines its superiority in use; that is, it can be easily calculated by using percentage distribution data.

General diversification measures can only integrate the number and size uniformity of sectors but cannot distinguish the degree of intersectoral differences and linkages. However, the differences and intersectoral linkages in various sectors must have different effects on economic growth and its fluctuations. Using the additivity of entropy, the previously mentioned entropy is decomposed into relevant diversification and irrelevant diversification:

$$K' = \sum_{i=1}^{n} q_{ij} \sum_{k=1}^{n} \sum_{k=n}^{m} \left[q_{ij} \left(\ln \frac{1}{p} \right) \right]. \quad (9)$$

Because the similarity of influencing factors of different economic indicators is low, the entropy index is defined as irrelevant diversity. The similarity of the same data is high, and the entropy calculated by taking the small department in the same large department as the unit is defined as correlation diversity.

Set the number of departments, namely, $k = 1, 2, 3, \ldots, K (K = 21)$; j is the number of small departments in the K large division. The first item in the formula-right is the related diversity (RV), which is the weighted sum of the lower entropy indicators composed of the share of the small sectors in the large sector, with the weight of

$$R_i = \sum_{k=1}^{n} p_j. \quad (10)$$

Among them, R_i is the weight of the index; p_i is the coefficient of the lower entropy.

3.2. Correlation Evaluation Model of Influencing Factors of Economic Fluctuation. According to the weight of the factors affecting economic fluctuations in the big data era determined as previously mentioned, to determine whether the economic indicators in this paper are effective indicators, it is necessary to determine whether the previously mentioned indicators are important factors affecting the economic fluctuations in the big data era according to the calculation of weight.

First, through the clustering algorithm, the influencing factors of economic fluctuations in the era of big data with large weight value are gathered into a set, and then, the data in the set are effectively collected as data input for the subsequent research of correlation evaluation model.

The steps of K-means algorithm are as follows: first, K samples of fluctuation influencing factors are randomly selected as the representative objects of K clusters. Calculate the distance between other samples and the center of K known clusters and add each sample to its nearest cluster. After assigning clusters to all samples, recalculate the average value of each cluster as the representative object of the cluster. Repeat the previously mentioned process until the samples in each cluster do not change. In practice, the sum of square errors is usually used as the objective function. As shown in the formula, when the value of the objective function does not change or changes below the set threshold, the final clustering result is obtained; that is,

$$\sigma = \sum_{i=1}^{k} \sum_{j=1}^{k} \left| w - c_i \right|^2, \quad (11)$$

where σ is the sum of squared error for all samples in the data set, and w represents a given single sample, and c_i is the mean of cluster C.

Then, the effective training is performed on the data in the set of economic fluctuations in the clustered big data era. The desired assignment was made to each fluctuation influencing factor index using the EM algorithm. The parameters of the mixed model were initially estimated and then repeated until convergence. Step E is called the expectation step, calculating the membership probability of each object according to the current parameter; the M step is called the maximization step, and the probability calculated by step E is used to update the parameter estimation. The probability of object O belonging to cluster C can be calculated by

$$T(t \in c_i) = \frac{T(c_i) t (t \in c_i)}{\sum T(c_i) t (t \in c_i)} \log T(c_i) \varepsilon (t \in c_i), \quad (12)$$

where $T(t \in c_i)$ represents obeying the mean, and $T(c_i) t (t \in c_i)$ represents the positive distribution of variance and the expected assignment coefficient.

Third, build the correlation evaluation model of influencing factors of economic fluctuations in the era of big data. In constructing the model, it is necessary to determine the occurrence probability of the correlation of the influencing factors of economic fluctuations. From the definition of probability, the probability of an event can be estimated by the frequency of the event in a large number of tests. When the sample size is large enough, it can be considered that the frequency of the event is its probability. Therefore, a large number of random sampling can be carried out for the random variables affecting its reliability, and then, these sampling values can be substituted into the functional function formula group by group to determine whether the structure fails, and finally, the failure probability of the structure can be obtained. The Monte Carlo method is based on this idea.

Assuming a statistically independent random variable $X_i = 1, 2, 3 \ldots k$, the corresponding probability density function is $f_x$and the functional number formula is $Z = g(x_1, x_2, \ldots, x_k)$. First, the value of group N random numbers $x_1, x_2, \ldots, x_k$ is generated according to the corresponding distribution of each random variable, and the correlation evaluation model of economic fluctuation influencing factors in the era of big data constructed is

$$\min \delta (X_i) = \frac{1}{n} |w|^2 + \frac{k}{l} \sum \left(s_i + s_j \right), \quad (13)$$

where δ represents the penalty coefficient, s_i represents the control fitting parameter, and s_j represents the dual coefficient.

Finally, input the set of economic fluctuation influencing factors in the trained big data era, and output the index correlation of the determined influencing factors; namely,

$$L(x) = \sum_{i=1}^{k} \left(s_i + s_j \right) \phi + b, \quad (14)$$

where ϕ represents the correlation regression coefficient and b represents the nonlinear relationship index.

To sum up, in the correlation evaluation model of economic fluctuation influencing factors constructed in this study, first, the clustering algorithm is used to gather the indicators into a set. After giving the index expectations, the Monte Carlo method is used to construct the correlation evaluation model of economic fluctuation influencing factors, so as to complete the analysis of economic fluctuation influencing factors in the era of big data.

4. Experimental Analysis

4.1. Experimental Scheme Design. In order to verify the effectiveness of this method in evaluating the influencing factors of economic fluctuation, an experimental analysis is carried out. In the experiment, a medium-sized and large enterprise in a certain place was taken as the research object. According to the changes of the enterprise's economic development in the past year in 2020, the key factors affecting the enterprise's economic change were set in the experiment, quantified, and evaluated according to the method setting. The parameters in the experiment are shown in Table 2.

4.2. Experimental Index Design. According to the previously mentioned experimental scheme, the comparative experiment is carried out using the comparative method. In the experiment, by comparing the methods of this paper and literatures [6] and [7], the correlation of the analysis index system and the accuracy of the calculation of the influencing factors are the experimental indexes. In order to ensure the accuracy of the experiment, the results obtained in the experiment have been iterated for many times.

4.3. Analysis of Experimental Results. In the experiment, first, the correlation of this method and the methods of literatures [6] and [7] on the sample economic data index system is analyzed. The correlation in the experiment takes the correlation coefficient as the research object. In the experiment, the value range of the coefficient is [0-1]. The larger the coefficient, the higher the impact of the determined economic impact index and fluctuation change. The experimental results are shown in Figure 6.

By analyzing the experimental results in Figure 6, it can be seen that the correlation of the sample economic data index system determined by the methods of this paper and literatures [6] and [7] is different. It can be seen from the experimental results that the correlation coefficient of the economic data impact indicators determined by this method is high, up to 0.92, and the lowest is about 0.80. The correlation coefficient of the economic data impact indicators determined by the methods of literatures [6] and [7] fluctuates more. Compared with this method, the fluctuation range of this method changes less, and the correlation is higher. This is because the calculation methods of key influencing factor indicators are defined through different algorithms. On this basis, the entropy law method is used to determine the weight value of indicators, and the clustering algorithm is used to gather the influencing factor indicators of economic fluctuation in the era of big data into a set to construct the influencing factor indicators of economic fluctuation, which improves the effectiveness of this method.

In the experiment, the accuracy of this method and the methods of literatures [6] and [7] on the calculation of sample economic impact indicators is analyzed. The results are shown in Figures 7–9.

Table 2: Experimental parameter design.

Parameter	Data
Number of evaluation indicators/piece	100
Value range of interference coefficient	[0, 1]
Test interval/S	0.5
Iterations/time	100

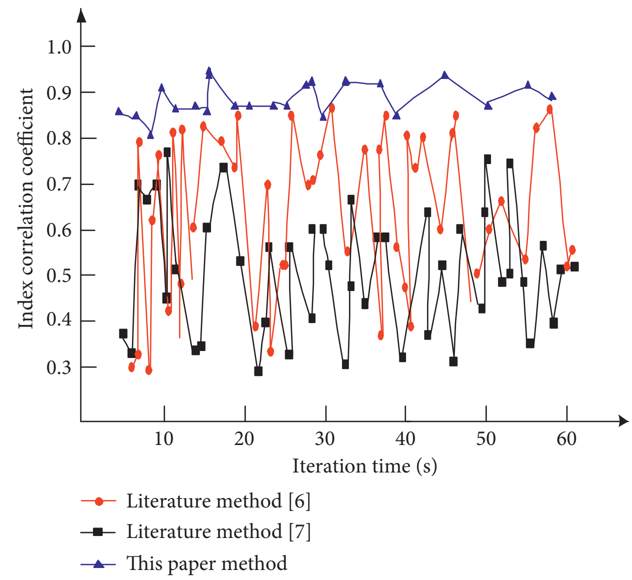

Figure 6: Correlation analysis of economic data index system determined by different methods.

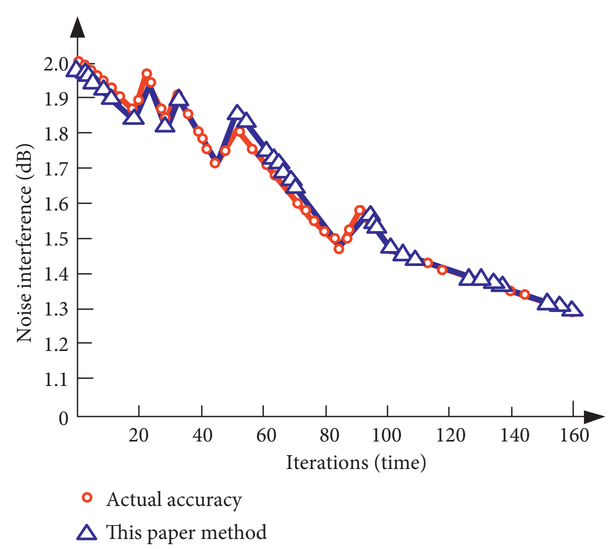

Figure 7: Precision results of sample economic impact index calculation by this method.

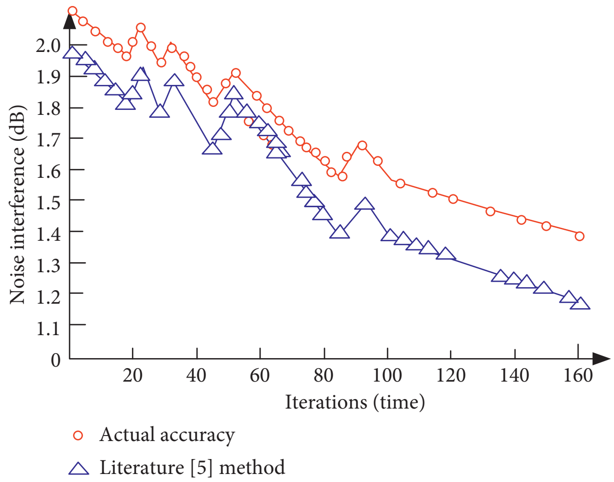

FIGURE 8: Precision results of sample economic impact index calculation by the method of literature [6].

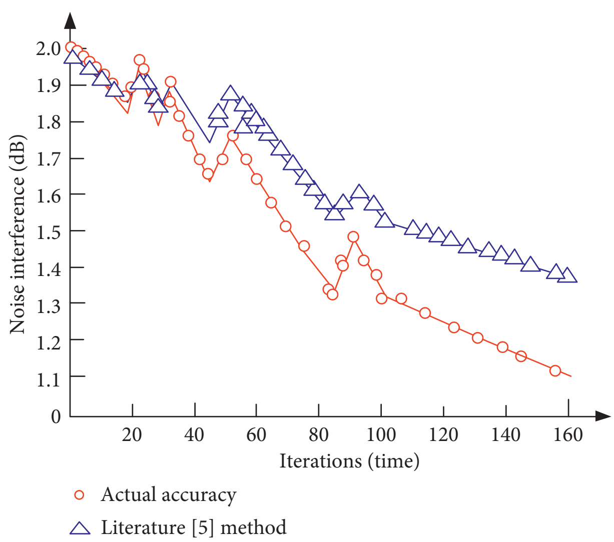

FIGURE 9: Precision results of sample economic impact index calculation by the method of literature [7].

By analyzing the experimental results in Figures 7–9, it can be seen that there are some differences in the accuracy of sample economic impact index calculation using the methods in this paper and literatures [6] an [7]. Among them, the accuracy of the sample economic impact index calculated by the method in this paper is relatively consistent with the actual calculation results. The accuracy of the sample economic impact index calculated by the methods in literatures [6] and [7] is different from the ideal value, and there are certain fluctuations. In contrast, the calculation accuracy of this method is better.

5. Conclusion

(1) With the continuous change of the economic environment, the index system of the existing economic fluctuation influencing factor analysis methods is less relevant. Therefore, this paper studies the economic fluctuation influencing factor analysis method in the new big data era. After clarifying the index system of influencing factors of economic fluctuations in the era of big data, the entropy law method is used to determine the weight values of different indicators. Then, the indexes are clustered into a set by clustering algorithm, and the EM algorithm is used to give the expected value of the data in the set. Finally, the Monte Carlo method is used to build the correlation evaluation model of the influencing factors of economic fluctuations to complete the analysis of the influencing factors of economic fluctuations in the era of big data.

(2) The experimental results show that the correlation coefficient of the influencing factors of economic fluctuations in the big data era analyzed by this method is high, the calculation accuracy of the influencing factors is high, and it is feasible.

(3) In the next research, we will further refine this analysis method, consider applying it to different fields, and expand the applicability of the analysis method.

Data Availability

The dataset can be accessed upon request.

Disclosure

This paper is the phased research result of 2021 university-level scientific research project “Research on World Skills Competition Freight Forwarding Project Based on Hubei Commercial Logistics Industry Chain” (project no.: S2021002).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Implementation of Multidimensional Environmental-Economic Collaborative Management in IoT Environment

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The Internet of Things (IoT) has gotten a lot of attention as a next-generation Internet application, and its realization, which connects things, people, and things, is the focal point of a new round of high-tech competition around the world. Network technology has a significant impact on people's lives today, thanks to the rapid development of the Internet, and the Internet of Things (IoT) is a technological innovation of the times that promotes the development of information technology. The Internet of Things has given the logistics industry a new lease on life, allowing it to grow more intelligently. The modern logistics industry is a modern service industry that includes transportation, warehousing, freight forwarding, information, and other industries, and it is very important. This paper examines the technical system of the Internet of Things and the logistics economic management mode, as well as the impact of the Internet of Things on logistics economic management. A multidimensional collaborative management model of environment and economy is proposed, based on the background of IoT. It has laid the groundwork for the IoT's application and development in the logistics economy.

1. Introduction

The world is linked by electronic communication technology. It is possible to connect things thousands of miles apart, which has greatly aided the advancement of human communication [1]. The traditional logistics system has proven insufficient to meet today's development needs. The logistics industry's previous business model is changing. The state has previously paid attention to the logistics industry, which is represented by railway [2]. In recent years, IoT technology has aided the logistics industry's informatization, automation, and integration, as well as its overall development. In the process of information technology development and logistics service diversification, modern logistics collaborative management is a new logistics management problem [3, 4]. New problems in logistics management have emerged as a result of the Internet of Things. In this case, the logistics industry should seek out new approaches.

In recent years, China's Internet technology is constantly improving. Internet technology has gradually changed to IoT technology. IoT technology has broken the traditional Internet virtual environment. The IoT can combine the network and objects, so that the real and intelligent self-perception can be connected with objects, so as to achieve the purpose of global interconnection. As the main application of the next-generation Internet, it has received extensive attention [5]. At present, the development of Internet technology has gradually transformed logistics into the IoT. Through the development of IoT technology, the logistics industry and Internet technology are continuously integrated [6]. The logistics industry needs to adapt to the new features and seek the best method for the transformation of the logistics industry in the IoT [7]. In the logistics industry, the use of modern IoT technology can have a strong impact on the traditional logistics economic management, reestablish the recognition of logistics enterprises for science, technology, and information, improve the intelligent monitoring and management of logistics enterprises, promote the sharing of information resources among logistics enterprises, and finally achieve the purpose of win-win.

The logistics industry will usher in a comprehensive innovation against a modern backdrop. The use of IoT technology in the logistics industry can help to improve the logistics industry's operational efficiency, improve the quality of logistics work, and aid in the development of China's logistics industry [8]. IoT is a technology that perceives, analyzes, controls, and manages goods using integrated technologies such as intelligent sensing systems, computers, and the Internet. The IoT's emergence and development will inevitably bring certain opportunities and convenience to the development of modern logistics, particularly in the visualization of logistics transportation, intelligent transportation, and logistics information networking, where the benefits of the IoT are clear [9]. The current cloud computing expertise can largely stabilize IoT expertise, which can improve logistics economic management work efficiency and reduce the likelihood of problems at work [10]. This paper introduces the multiagent collaboration mode of modern logistics network layer under the cooperative game and the multidimensional collaboration classification of modern logistics, starting with IoT-related knowledge. It was decided to create a multidimensional environmental-economic collaborative management model. Information collaboration can significantly improve the efficiency of the logistics economic system and bring more economic effects, according to simulation and numerical experiments.

2. Related Work

Literature [11] expounds management synergy from the perspective of economic management. Zhou and Yuan [12] pointed out that the synergy between various social departments is not strong, resulting in the low efficiency of social management. Therefore, in order to improve the efficiency of social work, a mechanism of social synergy must be formed. The research on collaboration in [13] is specific to the management level. Literature [14] holds that collaboration is a simple combination of individual parts, which forms the overall state and business performance of the enterprise. Literature [15] regards the whole supply chain as an evaluation subject and believes that it is more practical and scientific to establish a group rather than a single evaluation index. Literature [16] uses economics to analyze and define synergy: the value of the enterprise as a whole is greater than the simple sum of individual components, and the effect of collaboration is far greater than that of individual operation, which is the reason for the emergence of economic scale. Literature [17] believes that collaboration can maximize the utilization of resources. Resources can be divided into two types: one is entity resources. Literature [18] pointed out that, in the face of the rapidly changing market environment, enterprises need to seize the fleeting market opportunities and effectively integrate intellectual resources. It is necessary to form a mechanism—management synergy. Literature [19] proposes that management collaboration is not a natural selection process. In order to ensure the smooth operation of the enterprise system, managers understand the development of the enterprise system and the changes of the environment from multiple angles. This behavior process aims to explain why enterprise systems need management collaboration. Literature [20, 21] believes that a good measurement standard should involve these key elements of the logistics process: time, distance, and capital. Literature [22] believes that there are many ways for enterprises to realize collaborative benefits, such as business behavior, information sharing, information flow, and so on. However, it does not mean that these means can completely solve the problem of synergy. The root cause is that sharing is limited. Only enterprises with innovation ability can truly realize synergy. Literature [23] believes that, with the wide application of Internet technology, collaborative logistics has become a new business model. This model focuses on the integration and unification of the overall value, attaches importance to the information sharing and collaborative operation between upstream and downstream partners of the supply chain, and forms a good business operation network environment by establishing efficient collaborative mechanisms and norms. Literature [24] pointed out that the information that can be shared is not only inventory and order information, but also sales information. Literature [25] analyzes the collaborative operation of regional logistics clusters. Literature [26] proposes a negotiation based method to solve the distributed project scheduling problem. It is pointed out that the information sharing can be improved by sharing the flexible information of enterprise dispatchers and improving the concentration and scheduling quality. Literature [27] proposed three modes of cooperative operation. According to the different degree and relationship of node members, it can be divided into point chain collaboration, line chain collaboration, and full chain collaboration. Literature [28] pointed out that qualitative analysis is the focus of current research, and there is a lack of discussion on quantitative research such as system collaboration level, system collaboration mode, and collaborative system construction. This paper studies the significance of multidimensional coordination of modern economy under the IoT system. Whether it is theoretical analysis or practice and application, a complete set of scientific theories and management methods are essential to guide the successful application of the IoT in the economic field. In this paper, based on the IoT environment, a multidimensional environmental-economic collaborative management model is established to solve the problem of economic management collaboration. Through simulation and numerical experiments, it is proved that information collaboration can significantly improve the efficiency of logistics economic system. The effectiveness of the algorithm is verified by numerical experiments. The results show that the algorithm can bring more economic effects.

3. Methodology

3.1. IoT. In recent years, China has developed IoT professional technology, which is an interconnection technology based on computer professional network technology. The Internet of Things (IoT) is a brand-new type of information and communication technology. It is an important component of the new generation of information technology as well as a critical stage in the "information" era's development. With the advancement of communication technology, the Internet of Things (IoT) has become an important guarantee for the growth of the logistics industry [18]. Because people can surf the Internet at high speeds on their mobile devices, the IoT technology development platform has a lot of room for growth. With China increasingly focusing on the development of the IoT industry, the IoT industry has emerged as China's primary technology. China's IoT industry grew and matured earlier, and it has now essentially formed a perfect IoT industry system. And the market's development of some fields has begun to take shape.

As the application of the next-generation Internet, the IoT has received extensive attention, and the realization of the IoT, which interconnects things, people, and things, is the commanding point of a new round of high-tech competition around the world. The technical system of IoT includes three levels: perception layer, network layer, and application layer. The sensing layer is mainly used to identify items through sensing devices, collect information data, and transmit data to gateway devices through transmission devices. The network layer will process the received information data to ensure the security and reliability of the data [29]. In the application layer, information is mainly shared across regions, information is analyzed, and intelligent management services under the IoT technology are realized.

The IoT is an information bearing system based on the development of Internet technology, computer technology, and network communication technology. The system can make the modules with independent functions communicate with each other. IoT technology mainly realizes the connection between objects through infrared positioning technology and Global Positioning System (GPS) technology and uses Internet protocol to combine the Internet with actual objects, so as to realize information sharing. In recent years, China's communication technology is also constantly improving, because today's mobile devices can use the high-speed network to access the Internet, so a lot of mobile device users have been increased, which directly shows that the opportunity of the IoT is coming.

3.2. Application of IoT Technology in Economic Management Industry. Perception technology, network communication technology, identification technology, system framework technology, security and confidentiality technology, and so on are all part of the IoT, which together form a massive technical system. The Internet of Things (IoT) is a new era information technology term that denotes the start of a brand-new information era. The Internet of Things (IoT) technology realizes the connection between things, and its core technology is the Internet, which it extends and expands in a sense, with the goal of expanding information exchange to include the exchange of things. In the logistics industry, the Internet of Things is primarily used in the technology of automatic bar code acquisition. The visual intelligent system can help different departments coordinate and unify, rationally allocate logistics processes, and improve the timeliness of logistics management, as well as improving the operational fluency and efficiency of transportation management, warehouse management, and customer information service management. Under the IoT, logistics economic management should create resource codes within logistics units so that logistics resources can be managed in a unified manner, and the authenticity and accuracy of resources must be ensured during the resource collection process. The Internet of Things can be used to create a visual logistics intelligent management system. To ensure that the circulation of articles is transparent and safe. Figure 1 depicts the visual intelligent management framework.

In the traditional logistics management, due to the influence of road, geographical location, and other reasons, the information collection ability of goods is limited, and it is difficult to realize all-round tracking of logistics information. However, the Electronic Prism Collimator (EPC) tag of the IoT has solved this problem. In the aspect of logistics economic management mode, with the rapid development of high technology, quota management mode has emerged, which has advanced management concepts and policies and is widely used in the logistics industry. The management system of quota management mode can promote the rapid development of logistics economy. Besides the quota for product delivery and storage, the comprehensive management of products also needs quota, so as to further clarify the consumption produced by products reaching customers and make the quota management mode of logistics enterprises exert the greatest benefits, thus bringing more economic effects.

Using supply chain management mode, logistics management can reduce transportation pressure and operation costs. The rest can be outsourced to other companies as long as businesses carefully build their own core industries. It can improve not only execution efficiency, but also customer satisfaction, achieve zero storage, and promote the maximization of logistics enterprise benefits in this way. The development of logistics enterprises will be more efficient and long-lasting if comprehensive logistics management capabilities are integrated.

The Internet of Things (IoT) has the potential to improve economic visualization. The most important point to remember during the practical application is to strengthen the integration between IoT technology and logistics economic management, so that the logistics economic management can be completed with greater quality. Electronic identification and analysis of goods can be accomplished using EPC electronic tag technology in logistics, which improves not only the efficiency of screening and distribution of goods, but also the accuracy and speed of distribution. At the same time, the Internet of Things plays an important role in logistics economic management statistics and calculations. It can quickly grasp data and calculate results based on the data, allowing for logistics economic management visualization.

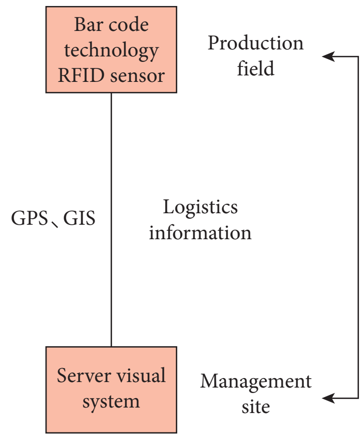

Figure 1: Visual intelligent management framework.

3.3. Economic Management of Multidimensional Collaborative Logistics under the Background of IoT. In the logistics industry, logistics economic management is one of the important works. The main responsibility is to plan, organize, command, coordinate, control, supervise, and encourage the whole process and systematic economic activities of logistics according to the basic economic laws and commodity circulation laws. With the support of IoT technology, the distribution speed of goods and goods information are more rapid and transparent. Goods do not need to stay in logistics companies for a long time, and the flow speed is accelerated. In the context of the IoT, combined with the basic characteristics of rapid logistics, bar code technology is set. When goods are converted or detained, as long as the bar code is scanned, the current transportation status of logistics can be displayed on the network platform through automatic identification. The multidimensional management of contemporary logistics economy has four characteristics. (1) Multidimensional. It includes technology collaboration, information collaboration, service collaboration, management collaboration, etc. (2) Coexistence. Each dimension promotes the others and does not hinder other dimensions. (3) Cooperation. It includes the competition and cooperation of different departments within the enterprise, different enterprises among industries, upstream and downstream supply chains of enterprises, etc. (4) Information sharing. The modern logistics industry is based on information network technology, which has realized a high degree of information sharing and real-time interaction and reduced departmental communication problems caused by information isolation. The multidimensional collaborative classification of logistics is shown in Figure 2.

Modern logistics is facing the necessity of multidimensional collaborative management. Based on the four-tier architecture of the IoT, aiming at the multidimensional collaborative management problems faced by logistics enterprises, this paper defines multidimensional collaborative classification from four dimensions, analyzes the phenomena of logistics enterprises in four-dimensional collaborative classification, and establishes the order parameter equation of logistics system. Suppose the system's cooperative efficiency is y, the nonhuman factor is x, and x is a function of time t. In the initial state of the system, the synergy efficiency is y_0, and in the lowest synergy efficiency state x_d, the synergy efficiency is y_d, and the balance synergy efficiency y_i; then:

$$y = \frac{\sin(x - x_i)}{x} + y_i, \quad x > 0. \tag{1}$$

Suppose the system's synergy efficiency is S, the nonhuman factor is γ, and S is a function of γ, so the formula (1) becomes

$$S(\gamma) = \frac{\sin(\gamma - \gamma_i)}{\gamma} + S_i, \quad \gamma > 0. \tag{2}$$

So S is the simultaneous function of ω, δ, ε, γ and η, ω, δ, ε, γ and η are also functions of time t, so

$$\frac{\partial S}{\partial t} = \begin{cases} \beta\omega(t) + S_{01}, & 0 < \omega < \omega_0, \\ 1n[\delta(t) + 1] + S_{02}, & 0 < \delta < \delta_0, \\ \arctan[\varepsilon(t) - \varepsilon_d] + S_d, & 0 < \varepsilon < \varepsilon_0, \\ \dfrac{\sin[\gamma(t) - \gamma_i]}{\gamma(t)} + S_i & \gamma > 0, \\ b\eta^2(t) + \sum S_n, & \eta > 0. \end{cases} \tag{3}$$

The macrochange of a complex logistics system is determined by the "synergy" between subsystems, not by the forced action of an external force. Whether it is technology collaboration, service collaboration, or management collaboration, it all starts with information collaboration and has an impact on information collaboration efficiency. The state formed by more than two collaborative requirements that are not of the same type is referred to as multidimensional. Modern logistics is confronted with a wide range of collaborative requirements. Storage space is not only an important index in the logistics industry, but also an important part of logistics economic management. Storage space is primarily used in the logistics link to store goods in the middle of logistics in order to ensure the integrity of goods and improve logistics efficiency during transportation or transshipment. IoT technology can help logistics companies improve their inventory management capabilities by allowing them to control warehouse storage information in real time, allowing them to check leaks and make up deficiencies in real time, and replenishing goods with insufficient storage in real time. The use of IoT technology condenses complex tasks while maintaining a high level of accuracy.

The mobile logistics service requesters and mobile logistics service responders are classified. According to the characteristics of logistics distribution, the nodes are divided into two categories. One is the mobile logistics service requester, represented by C_i; one is the mobile logistics service responder, represented by D_j. The trajectory information of the mobile node C in the practice period is expressed as

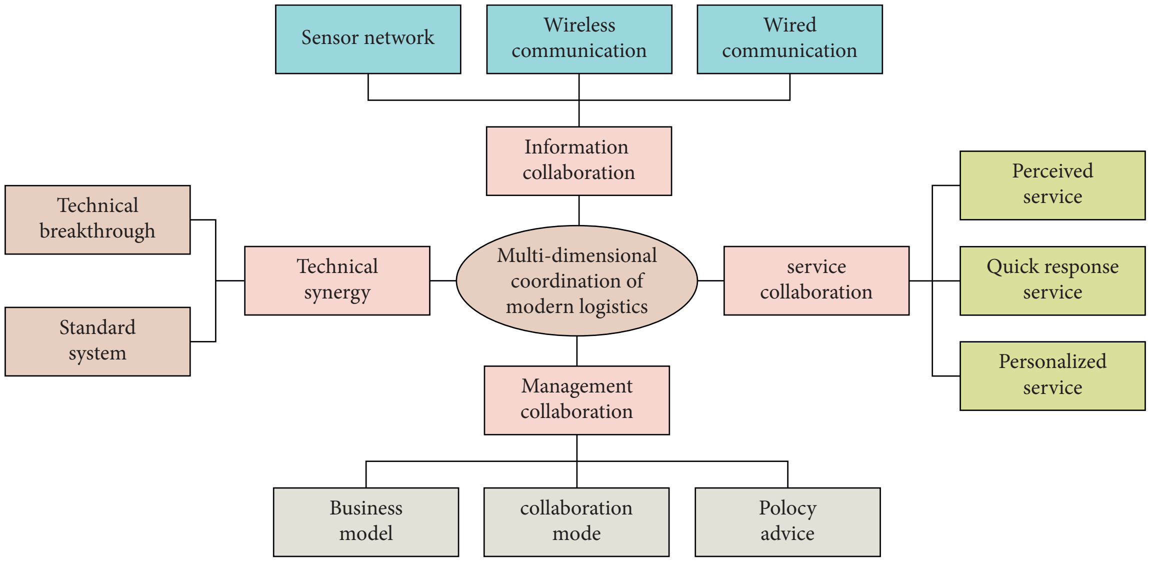

FIGURE 2: Logistics multidimensional collaborative classification.

$G = \{\cup_{i=1}^{k} L_i, S_i, E_i, \alpha\}$, where L is the location information of the sensing area, S and E are the time when the node arrives and leaves the area, and α is the time threshold, which is used to control the time interval for different nodes to reach the target area. The distance factor between nodes C and D is expressed as

$$L(C, D) = \frac{\sum_{i=1}^{k} \operatorname{sim}(G_i(C), G_i(D))}{T}, \tag{4}$$

where T is the time period; $\operatorname{sim}(G_i(C), G_i(D))$ is the position similarity function of mobile nodes C and D, which reflects the duration of different mobile nodes at position i, expressed as

$$\begin{aligned} &\operatorname{sim}(G_i(C), G_i(D)) = \max\{S_i(C), S_i(D)\} - \min\{E_i(C), E_i(D)\},\\ &\text{s.t} \begin{cases} L_i(C) = L_i(D) \\ |S_i(C) - S_i(D)| \le \alpha. \end{cases} \end{aligned} \tag{5}$$

There is a lot of information related to logistics, and there are extremely high requirements for accuracy and timeliness. In terms of logistics, information mainly includes inventory information, supply information, order information, purchasing information, etc. Controlling information is the most important thing in the logistics industry. Users can know the transportation time, destination, and so on of goods through the mobile phone terminal. This convenient technology can benefit both buyers and sellers. Automatic scanning technology can reduce the loss of goods, improve customer satisfaction, and make logistics and transportation transparent.

TSP_i is used to represent the distribution problem of the ith time slice, and N is the number of cities. $c_{i,j}(t)$ is the weight between city i and city j in time t, δt is the sampling period, $\Delta c_{i,j}$ is the change of weight between cities in the sampling period, T is the time period, and n is the sampling times in a period.

The distribution simulation problem based on collaborative information can be expressed as

$$\mathrm{TSP}(t) = \begin{cases} \mathrm{TSP}_1, & 0 \le t \le \Delta t, \\ \mathrm{TSP}_2, & \Delta t \le t \le 2\Delta t, \\ \dots & \\ \mathrm{TSP}_n(n-1), & \Delta t \le t \le n\Delta t, \end{cases} \tag{6}$$

$$o \cdot \min d(T) = \sum_{k=1}^{n} \sum_{i=1}^{N} \sum_{j=1}^{N} c_{i,j}(k \cdot \Delta t), \tag{7}$$

$$\begin{aligned} \text{s.t } \Delta t &= \frac{T}{n}, \\ \frac{\Delta c_{i,j}}{\Delta t} &= 0. \end{aligned} \tag{8}$$

Equation (6) indicates that the information-based collaborative delivery problem is a combination of different TSPs in different sampling periods. Among them, each TSP_i can be the same or different. When each TSP_i is the same, it becomes a traditional TSP; in the research of this article, they are different. Equation (7) indicates that the goal of completing the delivery is the sum of the target values of each TSP within the time period T; that is, it pursues overall goal optimization instead of local optimization. Equation (8) is the definition of the sampling period. Equation (8) indicates that the parameters in the sampling period remain unchanged.

People's production and lives will become more dynamic and refined in the IoT environment, and the way businesses operate will change dramatically. The Internet of Things (IoT) should be studied not only for its application of value-added, but also for the real difficulties and challenges faced by multidimensional collaborative logistics management in the IoT environment. Efforts should be made to incorporate IoT technology into all aspects of logistics management, as well as conduct targeted research to increase the value of its application in the field of logistics and provide greater benefits to logistics businesses.

4. Results Analysis and Discussion

The composition of IoT technology and logistics industry is relatively complex. By applying the IoT technology to logistics economic management, we can build an information-based network logistics public information platform. On this platform, customers can inquire about their own goods information at any time, so as to get the latest logistics information. Collaborative analysis is carried out from four levels: perception layer, network layer, application layer, and management layer, and the basic law of collaboration is summarized from the phenomenon of system self-organization and unbalanced phase change. Using quantitative analysis method, the multidimensional collaborative order parameter equation of modern logistics system is constructed.

The Internet of Things has the potential to greatly reduce the phenomenon of asymmetric economic information. It provides a profitable space for commercial banks because of the asymmetric information of small businesses in financing. The Internet of Things accurately and objectively reflects enterprise information, the market economy determines price, the transaction process is intuitive and transparent, and credit and risk assessment data are all open. The asymmetry of small businesses in the financial transaction process can be greatly reduced by analyzing network data. The most trusted technology in the application of IoT technology in logistics economic management is Internet information technology. Information transmission between various devices in the IoT system frequently requires the use of the Internet, which not only improves the rate of data transmission but also improves the efficiency of data processing. Perception technology is the foundation of the Internet of Things, allowing information management systems to "perceive" objects. Figure 3 depicts the market size and market segments of the IoT industry in China's modern logistics field from 2016 to 2020.

Because the application of perception technology has fueled its development, the demand for perception technology synergy has grown even stronger. The Internet of Things (IoT) is a technology that perceives, analyzes, controls, and manages objects using a variety of technologies such as intelligent perception systems, computers, and the Internet. The third information technology revolution is referred to as such. Under normal circumstances, logistics companies deal with a large volume of transactions and cargo transportation every day, so data calculation is a challenge for them. Traditional manual statistics and calculations are prone to errors when faced with such a large workload, and manual calculation is slow, making it difficult to grasp all data quickly. During this time, the IoT system can intelligently analyze goods, such as detailed classification of goods and specific sending areas, to ensure that goods in the same destination are managed and distributed uniformly, ensuring the efficiency of logistics work and the completion of logistics transportation and distribution in the shortest time possible. The real-time traffic information of this simulation system uses the congestion coefficient that obeys the time distribution as the input and divides the urban road traffic into two levels based on the frequency of road use, in order to simulate the real-time traffic information closer to the real situation.

Important path traffic: Urban arterial roads have a large traffic volume, and the road conditions are often in a saturated state. The traffic conditions of important paths are shown in Figure 4.

General route traffic: urban secondary roads and some branch roads. The travel time and frequency of people who use roads are regular, with obvious peaks and valleys in the morning and evening. The general route traffic conditions are shown in Figure 5.

The data in the IoT environment has a wide range of sources, a complex structure, and a large amount of data, and the data will be updated irregularly, so the data in the IoT environment has certain uncertainty. The IoT has certain advantages in mastering data and calculation results. To a certain extent, computers can replace people's work, which can quickly identify and merge logistics circulation characteristics, thus giving birth to barcode technology. "One thing, one standard" greatly facilitates the turnover and circulation of goods. Under the IoT environment, the application of IoT technology is conducive to the development of logistics economic management in the direction of intelligence. There are many independent logistics companies in China, but the information between them can be shared. Because the logistics information is updated very fast and the interaction is complicated, it is necessary to master the rapidly changing information with the IoT technology and increase the communication with other logistics companies.

Because the traditional simulation method takes the distance as the optimization goal and does not consider the road information, it cannot respond to the real-time road information in real time, and its path distance length has not changed significantly. However, when the main roads are congested, the simulation of information collaboration will choose other road sections with a little distance but good road conditions. Therefore, the whole distance will obviously increase during the peak period of traffic congestion. The analysis and comparison between the starting time and the whole distance is shown in Figure 6.

In the IoT environment, logistics development should provide timely feedback on information updates based on changes in various IoT data information, collect changes in information, adapt logistics development to market changes, know the market in real time, grasp the characteristics of big data changes in the IoT environment, and integrate information in real time, so that IoT data information can be integrated. To score the delivery service, receiving service, and online shopping satisfaction of logistics enterprises, choose 30 valid scoring data. The results are shown in Figures 7 and 8.

The continuous development of IoT economy will impact the traditional economic model, which will make adjustments in business composition, service object, service

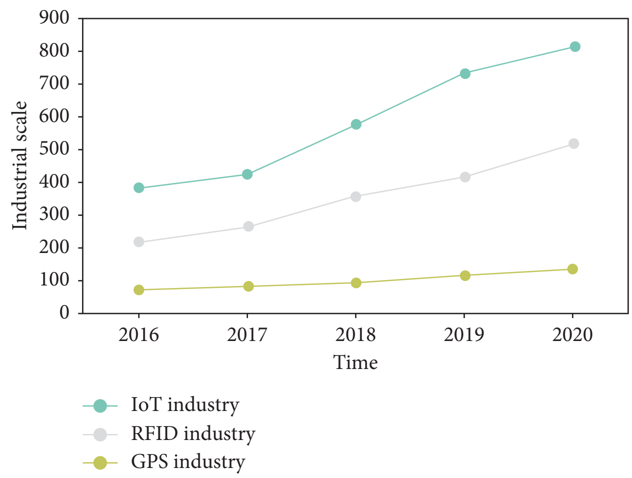

Figure 3: Market scale and growth of various industries in the field of intelligent logistics.

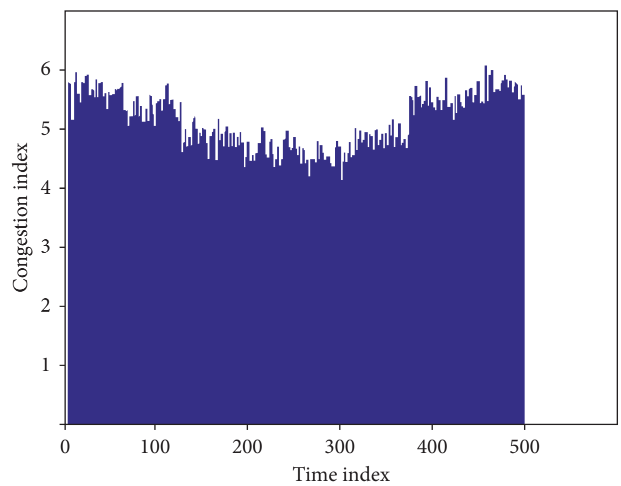

Figure 4: Traffic map of important paths.

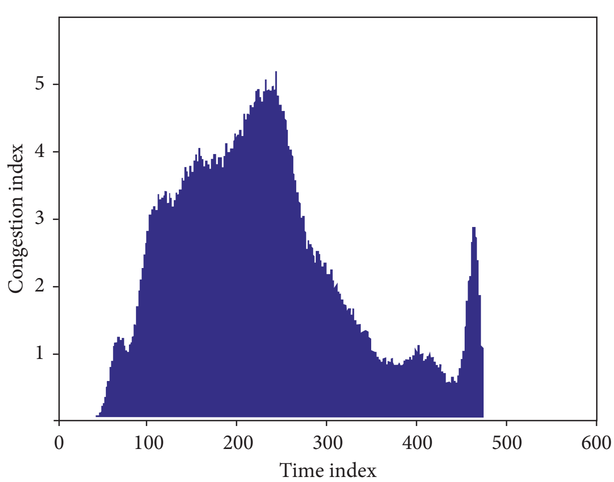

Figure 5: General route traffic map.

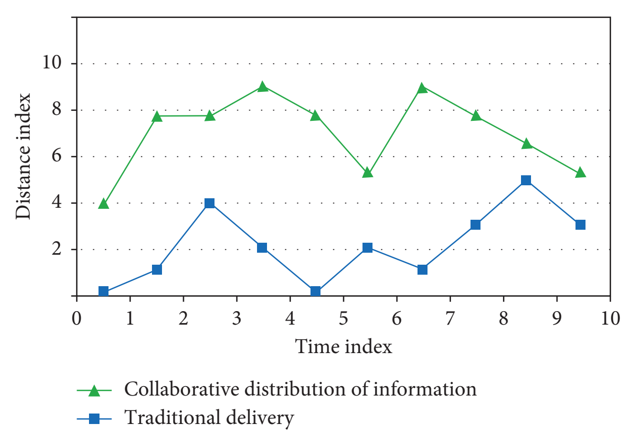

Figure 6: Comparison chart of starting time and full distance analysis.

attitude, and operation mode. Under the current background of the IoT, the logistics economic management has been innovated. Applying the IoT technology to the logistics economic management can effectively improve the quality and efficiency of the work, optimize the service functions of logistics enterprises in all directions, and enable customers to enjoy better logistics services.

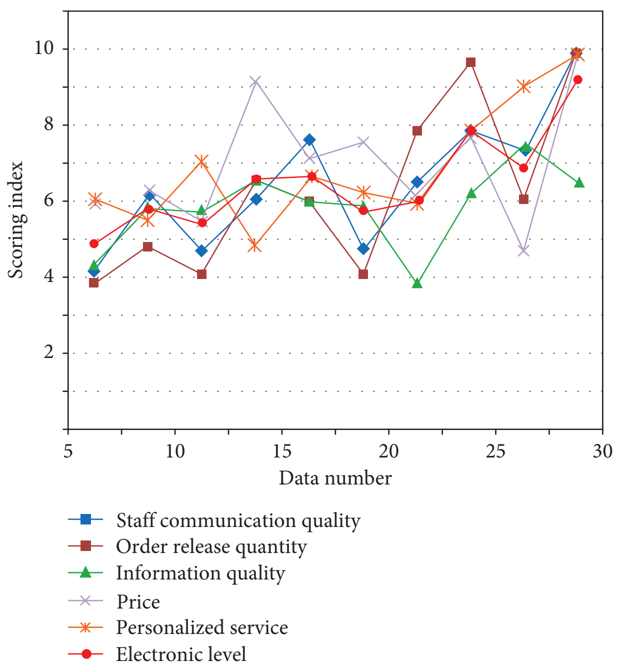

FIGURE 7: Online shopping satisfaction scoring results based on the Servqual scale.

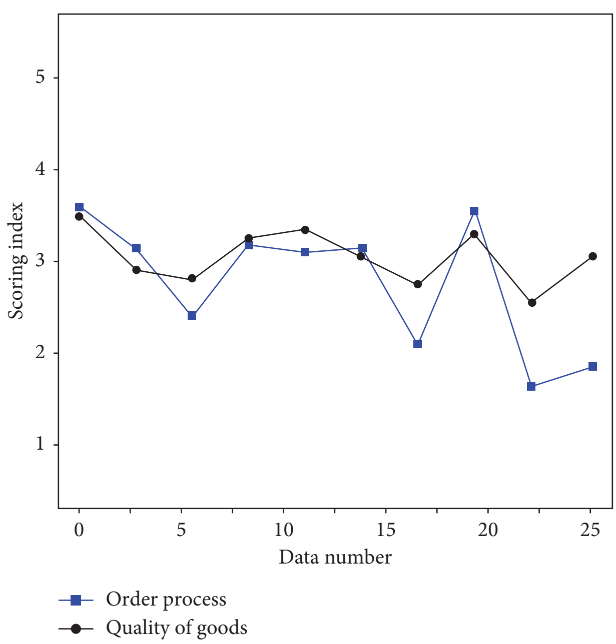

FIGURE 8: The scoring results of the quality of service delivery based on the Servqual scale.

By solving the equation with the algorithm, it is concluded that the information collaboration is the order parameter of the logistics system, which realizes the accurate use of the order parameter to control the fluctuation and balance of the logistics system and build a modern logistics collaborative service platform framework based on service-oriented architecture and solve the problem of service collaborative management through system platform and quality evaluation and improve the efficiency of logistics economic management.

5. Conclusions

The influence of the background of the IoT era on economic industry is revolutionary, and the IoT economy is the result of the full integration of computer network communication technology and economic industry. The application of the IoT has improved the running rhythm of modern logistics industry and has also made a revolutionary impact on the multidimensional collaborative management of modern logistics industry. From the current social logistics management process, it has almost subverted the operation mode of logistics. It has promoted the change of economic management concept, operation mode, and profit model and promoted the change of China's economic structure. It has formed innovative forms of financial circulation, such as payment, transaction, and financing, and provided convenience for financial business of all walks of life. Under the background of the Internet age, multidimensional collaborative management of environment and economy is necessary. The development of logistics industry plays a very important role in the transportation of logistics industry and promoting the growth of national economy. Although there are some problems in the IoT economic industry at present, with the supervision and guidance of the state in laws, regulations, and policies, the IoT economic industry will embark on a healthy, sustained, and stable road and become an important part of the driving force of China's economic development. In this paper, based on the IoT environment, the multidimensional collaborative order parameter equation of modern logistics system is constructed, and the simulation and numerical experiments verify that the model can significantly improve the efficiency of logistics system. This paper analyzes the influence of the IoT on the logistics economy, its application, and the problems to be solved at this stage, in order to help promote the development of the logistics industry.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

All the authors declare no conflicts of interest.

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Research Article

Value Analysis and Realization of Artistic Intervention in Rural Revitalization Based on the Fuzzy Clustering Algorithm

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Intervening in the revitalization and development of art villages is one of the ways to build regional brands in rural areas, fit in with contemporary aesthetics, and meet the needs of modern people for diversified life. At the same time, it is not limited by artistry itself, but a comprehensive artistic activity with modernity, industrial linkage, and sustainability. This paper uses the HPR (Hestenes–Powell–Rockafellar) multiplier method to solve and establishes a SSFCM-HPR (semisupervised fuzzy *C*-means clustering based on HPR) algorithm. The experimental results on datasets show that FCM-UserCF (fuzzy *C*-means-user collaborative filtering) algorithm effectively solves the problem of data sparsity and improves the accuracy of recommendation. Rural planning and design under the intervention of art is a kind of respect for local memory, an inheritance of folk crafts, a reshaping of history and culture, and an identification with the countryside itself. It also puts forward new development ideas and guiding methods for the sustainable development of rural areas.

1. Introduction

Rural areas, which are China's most difficult and pressing issue, are attempting to reshape rural order, protect ancient buildings in rural areas, and revive rural culture through art intervention. Rural revitalization has been a top priority of the Chinese government policy in recent years, and it is expected to continue to do so in the future. At the government level, China has issued a series of related policies in recent years, demonstrating the country's commitment and attitude toward rural revitalization. A new wave of development and construction has erupted in domestic villages, guided by the national rural revitalization strategy. Not only for rural material construction but also for multidisciplinary participation [1], creating beautiful countryside is a difficult and long-term task.

With the development of modernization and towns, rural society is facing the strong invasion of external modern culture, and there is also an endogenous cultural crisis. In the cultural environment of "coexistence of old and new," there are some problems in rural community culture, such as insufficient endogenous development power, insufficient innovation ability, declining vitality, and unsustainable development of traditional culture [2, 3]. Since the rural revitalization strategy was put forward, all parts of the country have responded one after another and continued to promote all-round inheritance and promotion of rural infrastructure construction, ecological environment management, and rural cultural custom protection [4]. Intervening in the revitalization and development of art villages is one of the ways to build regional brands in rural areas, fit in with contemporary aesthetics, and meet the needs of modern people for diversified life [5]. The uniqueness of contemporary Chinese villages is being dispelled, the traditional culture is being impacted, and the living environment has not been paid attention to and improved; instead, it has become an activity for artists to entertain themselves.

Involved in rural revitalization of art, it has unique advantages in creation design, ingenuity culture, cultural protection, and dissemination [6, 7]. Giving full play to the role of art is the inherent requirement of rural revitalization, and the involvement of art in rural construction has become the main practice of rural construction in China. Based on this, this paper explores the strategy of artistic mediation in rural design under the background of rural revitalization. This paper puts forward the value analysis and realization path of artistic intervention in rural revitalization based on FC (fuzzy clustering) algorithm, aiming at awakening villagers' cultural consciousness in cultural construction.

Based on the analysis and deduction of the four elements of the festival, this paper points out that, to meet the inherent demands of the four elements in the festival, the balance of each element can only be achieved through the corresponding linkage mechanism, which is also the necessary way to successfully hold the festival. The linkage mechanism is dynamic and flexible, which acts on the festival and also makes the festival produce different functions, meanings, and achievements under different backgrounds and conditions.

2. Related Work

How to involve the art festival in rural revitalization is not only a domestic topic but also a common concern of the whole world. If the scope discussed in this topic is further expanded—which is actually necessary—it should be extended to cities. In [8], from the perspective of social ecology, it is considered that the current rural areas present a "weak niche." Xu [9] used scientific experiments and stories to prove the practical "work" way of science and held that the so-called "culture" actually exists in a dynamic and constant "action." "Before the conflict with other people, no one lives in a certain ' culture,' enjoys a certain ' paradigm,' or belongs to a certain society. The emergence of these words is the result of expanding the network and crossing the alien crowd." Pan [10] made comprehensive statistics and research on the economic role, indirect benefits, comprehensive tourism income, and jobs provided by the art festival. Zhang et al. [11] presented a detailed description and evaluation of the public art and Art Festival on the coast. Shang [12] analyzed the development and ways of the creative industry through the case of ancient town drama festival.

The goal of clustering analysis is to divide a wide range of items into distinct categories (clusters). The things in each cluster have some similarities, and the things in different clusters have some differences. Clustering has been proven to be effective in a variety of scenarios and is an important research direction in big data mining. A new metric space based on the fuzzy induction topology was established in [13]. Unsupervised distance learning algorithm was proposed in [14, 15]. Researchers have been working on distance modification for the past two years. An unsupervised distance learning algorithm based on the DI-FCM (double-indices fuzzy C-means) algorithm framework—a double-index fuzzy C-means algorithm based on hybrid clustering learning HDDI-FCM (double-indices fuzzy C-means with hybrid distance)—was proposed in [16]. Karunambigai et al. [17] proposed a fuzzy scatter matrix-based clustering algorithm that aims to minimize the trace of the intraclass fuzzy scatter matrix while maximizing the trace of the interclass fuzzy scatter matrix, integrates hard and soft clustering, and assigns a hard core boundary to each class. A fuzzy kernel clustering algorithm with different attributes weighted in the feature space was proposed in [18], which can effectively deal with the clustering problems of linear inseparability and unbalanced attributes. A fuzzy kernel clustering algorithm based on comprehensive comparative analysis was proposed in [19]. These methods have partially solved the clustering problem for nonspherical distribution data, but the construction and selection of kernel functions, as well as the determination of kernel function parameters, have become new problems for these methods.

3. Research Method

3.1. Strategies and Methods of Art Intervention in Rural Planning and Design. As the birthplace of Chinese culture, the countryside bears Chinese excellent folk traditions, unique lifestyle, and behavior habits and is the resort of homesickness and the carrier of historical context. Under the influence of modernization and urbanization, in order to retain homesickness memory and historical context in the process of art intervention in rural planning and design, it is necessary to realize the mutual fit between the new and old environment in the process of art intervention and avoid tough intervention or conservative intervention.

Therefore, in the process of art intervention in rural planning and design, it is necessary to excavate rural local cultural resources to form the accumulation of original materials for art intervention [20]. For the excavation and acquisition of cultural resources, it can collect basic cultural resource materials, pictures and images of rural texture, style, beliefs, folk culture, and traditional skills through in-depth interviews, oral statements by the elderly, consulting documents and materials such as county records and rural history, on-the-spot investigation, and experience.

Historical cultural resources, celebrity cultural resources, religious cultural resources, folk cultural resources, and revolutionary cultural resources are the most common types of local cultural resources. To vividly express a variety of local cultural and artistic resources, to provide artistic design elements for art intervention in rural planning and design, and to extract the symbols of cultural elements needed for art to intervene in rural planning and design, it is usually necessary to analyze, classify, and screen the original materials, such as local cultural and artistic resources, combined with the needs of planning and design and the needs of villagers.

Typical local cultural element symbols have been formed after collecting, sorting, classifying, and refining the materials of local cultural resources. Then, using various artistic design techniques, these typical local cultural elements are transformed into "artistic design symbols" with special rural significance and finally applied to artistic intervention in rural planning and design to realize the fit between the new and old environment. The model of strategies and methods involved in artistic rural planning and design is shown in Figure 1.

Involved in artistic rural planning and design, the rural local cultural resources are first excavated through the oral method of the elderly and the method of consulting

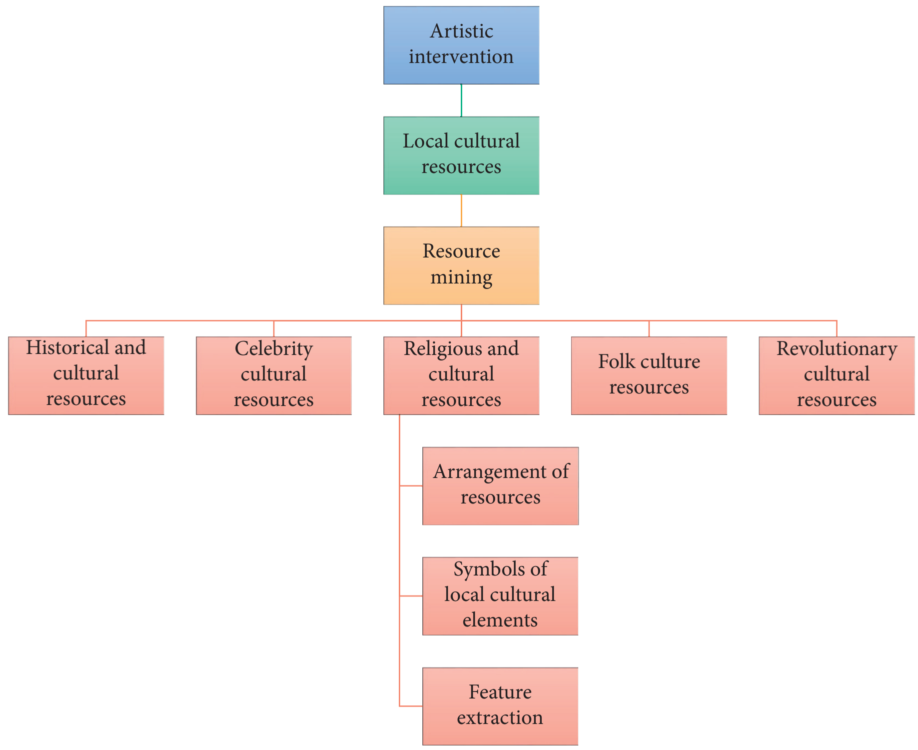

FIGURE 1: Strategy and method model of artistic rural planning and design.

documents and materials, and then the characteristic and typical local cultural element symbols are extracted by analyzing, classifying, and screening them in conjunction with the design needs and the needs of the villagers in order to complete the planning and design investigation and design analysis. The extracted symbols of local cultural elements are then refined in terms of color, shape, structure, texture, connotation, and other characteristics to form basic artistic design elements, and the local cultural resources are transformed into artistic forms using design techniques such as extension and reproduction, transformation and utilization, integration, and innovation. Finally, the art form is applied to the planning and design of rural art.

3.2. Analysis of the Semisupervised FCM Algorithm for Artistic Intervention. Because the rural culture is formed in the long-term local practice, it has the characteristics of life and locality and has a strong regional character. The cultural consensus formed by the community for a long time is the glue of the rural society, so the cultural break is likely to affect the stability of social order. Therefore, in the process of rural cultural revival, it is necessary to repair the cultural and social fractures caused by man-made in the social transformation, attach importance to the cultural value of local traditions, reshape the rural community through cultural revival, and rebuild the rural community identity.

The rational choice principle of choosing to use more advanced and efficient tools in human social changes cannot be changed, but although the old culture no longer has the tool value, its cultural value has become more important. Therefore, seeing that some valuable local cultures that have recorded human civilization for many years are gradually dying out, it needs to show our attitude and take practical actions to protect, inherit, and develop those most distinctive cultures and skills and record and preserve these living fossils of human civilization for future generations.

FCM (fuzzy C-means) is a typical FC algorithm, which applies fuzzy technology to the traditional C-means algorithm and has been proved to be one of the most effective clustering methods by practice [21]. However, FCM algorithm needs many iterations in the process of operation, and when the amount of data is particularly large or there are many attributes of data samples, the operation speed will be greatly reduced. The algorithm of SSFCM-HPR (semi-supervised fuzzy C-means clustering based on HPR (Hestenes–Powell–Rockafellar)) is proposed.

Assume that the number of clustering samples is $n_s + n$, among which n_s are labeled samples, n are unlabeled samples, and n_1 belong to the first class, $n_2 + n_1$ belong to the second class, and $n_s + n_{s-1}$ belong to the s class. Let the classification number be c and the membership matrix be $U = (U', U)$.

The expression of distance measurement between the sample and cluster prototype is defined as

$$\begin{aligned}(d_{ik})^2 &= \|X_k - P_i\| \\ &= (X_k - P_i)^T W (X_k - P_i),\end{aligned} \tag{1}$$

where W is the characteristic weighting matrix.

Because all the samples are independent of each other so that the columns of the partition matrix U' are independent of each other, one column of the partition matrix U' can be chosen as the research object. For the convenience of research, the kth supervised sample can be chosen as the research object. Because when k is determined, its corresponding labeled is also determined; that is, the category j is a known quantity.

$$\min J_k = \sum_{i=1}^{c} (u_{ik}^{*})^m d_{ik}^2,$$
$$\text{s.t.} \begin{cases} \sum_{i=1}^{c} u_{ik}^{*} = 1, \\ u_{ik}^{*} + \Delta u - u_{jk}^{*} + y_{ik}^{*} = 0, \quad i = 1, 2, \ldots, c, \; i \neq j. \end{cases} \tag{2}$$

For unsupervised samples, because the constraint conditions of membership degree have not changed, the formula of membership degree is the same as that of traditional FCM algorithm:

$$u_{ik}^{*} = \frac{1}{\sum_{l=1}^{c} \left(d_{ik}/d_{lk}\right)^{2/m-1}},$$
$$k = 1, 2, \ldots, n; \quad i = 1, 2, \ldots, c. \tag{3}$$

Because the solution of the clustering objective function is an iterative optimization process, if the weight of the k supervised sample is ω_{k,k_1} in the k_1 iteration, then

$$\omega_{k,k_1} = \frac{u_{jk,k_1-1}^{*}}{\max\limits_{i\in\{1,\ldots,c\}, i\neq j}\left(u_{ik,k_1-1}^{*}\right)}. \tag{4}$$

In the above formula, $j = \operatorname{argmax}_{i\in\{1,\ldots,c\}} (u_{ik,k_1-1}^{*})$.

3.3. Intervene in the Realization of Art and Rural Revitalization. Action that is based on participation art intervention, also known as social art intervention, is a type of art intervention that is commonly used in rural areas. Its art is based on field research and refined from the unique regional culture of rural areas, with a stronger emphasis on the intermediary nature of art action and the creation of rural regional culture. Intervening in artistic rural design is to revalue and repair the rural value and reconstruct the relationship between man, nature, and ancestors with the help of rural design, whose core elements are to repair rural production and life, ecosystem, rural social order, and ethical relationship and to promote the emergence and development of new industries and new platforms in rural areas. The restoration of the rural cultural system and ethics, paying attention to the explicit expression and invisible inheritance of rural culture, inspiring public participation and a sense of ownership, and creating a rural space rich in appreciation value are at the heart of artistic intervention in rural design. Art in rural areas not only preserves rural culture's unique value but also facilitates the exchange of rural information and improves the countryside's inclusiveness and openness.

At present, the countryside is facing a serious hollowing phenomenon, and rural public life is gradually declining. In order to revitalize rural public space, artists launched a series of artistic practice activities. By means of art and culture, the symbol resources can be transformed, and a new image of artistic villages and cultural villages with relaxed and rich cultural atmosphere can be created with lightweight rural field art creation. The artistic expression forms include overall planning of rural space, dot space art design, linear street space design, and area space art design. At the same time, reconstruct the villagers' public life, complete the reconstruction of rural capital through collective activities, enhance the display of rural cultural individuality, and promote the rural production and life sustainably.

The basic idea of FCM-UserCF (fuzzy C-means-user collaborative filtering) algorithm designed in this paper is as follows: firstly, FCM algorithm is used to cluster users with similar backgrounds into the same cluster to reduce the dimension of the matrix; then, the data matrix is preprocessed by Slope One algorithm, and the unrated data in the matrix are predicted and filled, so as to solve the disadvantage of the sparse user-item scoring matrix; finally, CF (collaborative filtering) is carried out based on the filled scoring matrix.

The FCM-UserCF algorithm can be disassembled into two steps: step 1: according to the background information of users, use FC to make the background of the same user group similar; step 2: fill in the missing data of the scoring matrix and make recommendations through the UserCF algorithm in CF.

FC algorithm needs to generate a membership matrix, and a fuzzy similarity matrix needs to be built for the data similarity in the matrix [22]. There are many methods to construct the similarity matrix, including the maximum-minimum calculation method, cosine angle method, and correlation coefficient method. In this article, the fuzzy similarity matrix $R(r_{ij})_{m\times n}$ is constructed by calculating the similarity statistic r_{ij} of data by using the maximum-minimum method, and the formula is

$$r_{ij} = \frac{\sum_{k=1}^{m} \min\left(x_{ik}', x_{jk}'\right)}{\sum_{k=1}^{m} \max\left(x_{ik}', x_{jk}'\right)}. \tag{5}$$

Among them, $i = 1, 2, \ldots, n$; $j = 1, 2, \ldots, m$, n represents the number of data pieces, m corresponds to the category that is the number of cluster centers, and x' represents the elements in the membership matrix.

Based on all scoring items $I_{ui} = I_u \cup I_i$ of users u and i, if there are missing scoring items in all items, the Slope One algorithm can be used for prediction. Calculate the target user U rating $P(u_j)$ for item j.

$$\text{dev}_{(j,i)} = \sum_{u\in I\cap J} \frac{u_j - u_i}{\text{num}(I\cap J)},$$
$$p\left(u_j\right) = \frac{I}{\text{num}(R(u)\cap D(j))} \sum_{i\in R(u)\cap D(j)} \left(u_i + \text{dev}_{(j,i)}\right). \tag{6}$$

In the formula u_i, u_j refers to the true score made by user U on item i, j, $\text{num}(I\cap J)$ refers to the number of all users who score the intersection of item i, j, $R(u)$ refers to all scoring items of user U, $D(j)$ refers to all average deviation value items calculated with item j, and $\text{num}(R(u)\cap D(j))$ refers to the intersection number of all items of $R(u)$ and $D(j)$.

The FCM-UserCF algorithm proposed in this article needs to cluster the dataset by FCM algorithm according to the user background information so that the user background information within the same class is similar after clustering; Figure 2 shows the specific flow of FCM-UserCF.

The planning of traditional rural folk cultural and artistic activities reflects the cultural significance of rural space, explains village characteristics, and influences villagers' daily lives and values. This emphasizes the critical role of traditional rural folk culture and art activities in art intervention in rural planning and design. The goal of planning and developing traditional rural folk culture and art activities is to improve the quality of life for villagers. As a result, the needs of villagers' lives should be the starting point for planning traditional rural folk culture and art activities. In conjunction with the trend of people flow, attention should be paid to the layout and creation of artistic space and cultural creative space, particularly in rural public space and places where people flow gather, as these are the places that can best influence and drive villagers' thought and value identity, as well as promote cultural communication.

Today's rural revitalization needs to pay attention to the long-term investment and long-term interests of rural industries. The goal of rural revitalization is to establish long-term regional brands and regional products that are compatible with them, cross-border, and diversified. The participation of art in regional brand building in rural areas is one of the most direct and effective ways to realize rural revitalization and promote rural sustainable development, and it is also one of the important contents of top-level design in rural revitalization.

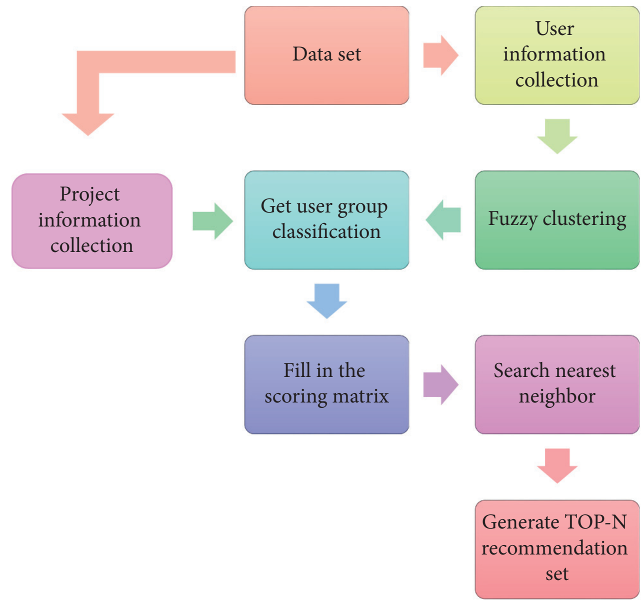

Figure 2: Flowchart of FCM-UserCF algorithm.

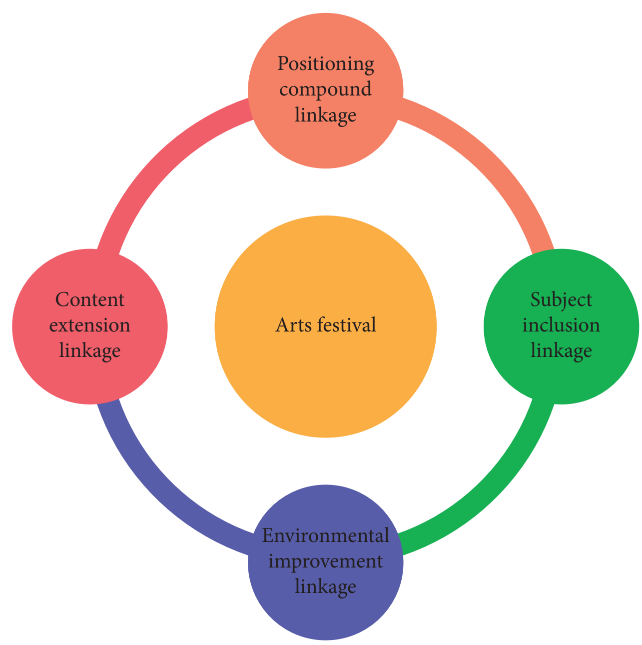

Figure 3: Illustration of the linkage mechanism of the art festival.

4. Results' Analysis and Discussion

4.1. Discussion on the Linkage Mechanism of Art Festivals Involved in Rural Revitalization and Development. Under the tide of China's economic development, the cultural ecology is constantly tearing, reorganizing, and constructing, especially in rural areas, where constant cultural acculturation makes the cultural ecology very fragile. However, it is impossible and undesirable to return to the traditional cultural ecology. The festival is a good choice in terms of the feasibility of the measures, the remarkable effect, and the cohesion of the organization.

The last step-by-step process of the festival is not a one-step process. After the completion and implementation of the whole art planning, diverse subjects will have different feedbacks. According to the feedbacks, the content of the festival will be constantly adjusted and enriched, and all of them need to operate the festival sustainably through four linkage mechanisms (Figure 3).

To begin with, the festival's origins are based on a variety of interconnected and contradictory demands from multiple subjects, as well as a need to coordinate problems across subjects through inclusive linkage. Second, the festival's surroundings are important amenities that contribute to the festival's uniqueness. As a result, strengthening the linkages to promote the win-win goal is necessary to protect the natural environment, make the best use of the situation, and tap potential. In the industrial chain, the life chain will work. Operating institutions, investment funds, and various modes of operation are all part of the industrial chain. The festival's theme is an ecological chain that will grow and connect to other ecological chains.

4.2. The SSFCM-HPR Algorithm Is Used to Analyze the Dataset. The clustering result of SSFCM-HPR algorithm is shown in Figure 4, and the clustering result is very ideal. It can be seen from Figure 4 that when the supervised samples contain outliers, SSFCM-HPR algorithm can handle the supervised outliers well so that it can correctly guide the clustering process.

China's rural revitalization is a road of all-round development, and it is an all-round revitalization of industry, ecology, local civilization, and quality of life. Through industrial implantation, ecological environment governance, and promotion, excavation, and activation of local culture, we can retain the local resident population, let urban people return to their hometowns to start businesses, change the rural population structure, reduce population loss, and improve the civilized quality of the whole rural population. Therefore, "people" are particularly important in the whole rural revitalization.

The IRIS dataset is classified by traditional FCM algorithm, FCM algorithm based on feature weighting, and SSFCM-HPR algorithm. The results are shown in Figure 5.

SSFCM-HPR algorithm has the lowest misclassification rate, and with the increase of the number of supervised samples, the recognition rate is significantly improved [23]. When the number of supervised samples is 7, IRIS datasets can be completely separated correctly.

In order to further illustrate the practicability of this algorithm, two face databases, ORL face database and YALE face database, are used for experiments [24]. PCA [14], LDA [15], LPP [16], and MFA [17] algorithms are used for comparison, and the experiments are repeated for 20 times. Figure 6 shows the average recognition rate of various algorithms.

SSFCM-HPR algorithm can better guide the clustering process. Of course, compared with SSFCM-HPR algorithm, FCM_DNE algorithm also has its own characteristics: FCM_DNE algorithm can effectively alleviate the dimension disaster problem in high-dimensional data classification, and at the same time, it maps data to low-dimensional space, which reduces the computational cost of FCM algorithm.

In order to further illustrate the robustness of this algorithm, now, discuss the situation when the label information of the supervision sample is wrong. For the data provided by Kong et al. [18], when labeling the supervision samples, this paper specially gives the supervision samples with wrong classification information. The 2nd, 10th, 41st, and 55th special samples are taken as supervised samples, and two misclassified samples are produced by using Bensaid–Bezdek algorithm. Using SSFCM-HPR algorithm, the result is shown in Figure 7, and there is no misclassification sample. The experiment shows that this algorithm is insensitive to the "typicality" of supervised samples.

Figure 8 shows the membership degree of each sample belonging to the first class when the α-value takes some representative values. Obviously, when α is 5, the ideal classification result is not obtained, and when α is 6 or above, the classification result is ideal.

Although the supervised sample's membership value approaches the labeled membership value as the scale factor is increased, the clustering results of the SSFCM-HPR algorithm are very sensitive to the value of the scale factor, and when the value is small, the role of the supervised sample cannot be displayed, and the clustering results tend to fall into a local optimum, resulting in clustering failure. The

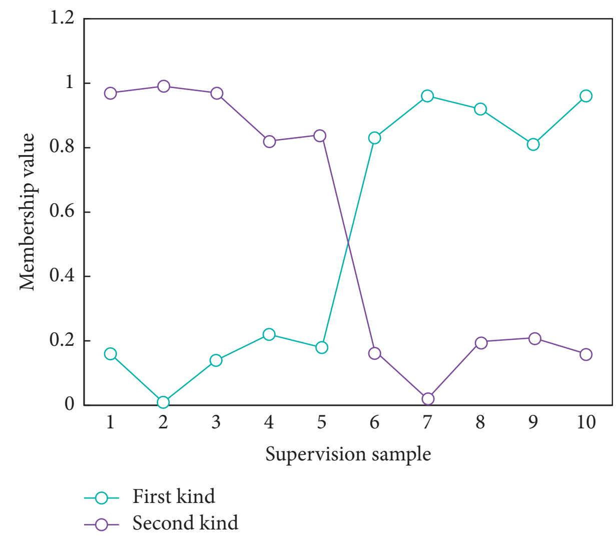

FIGURE 4: Classification results of datasets by SSFCM-HPR algorithm.

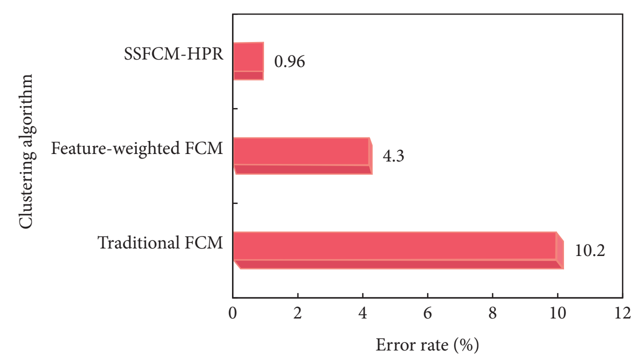

FIGURE 5: Clustering results of different algorithms.

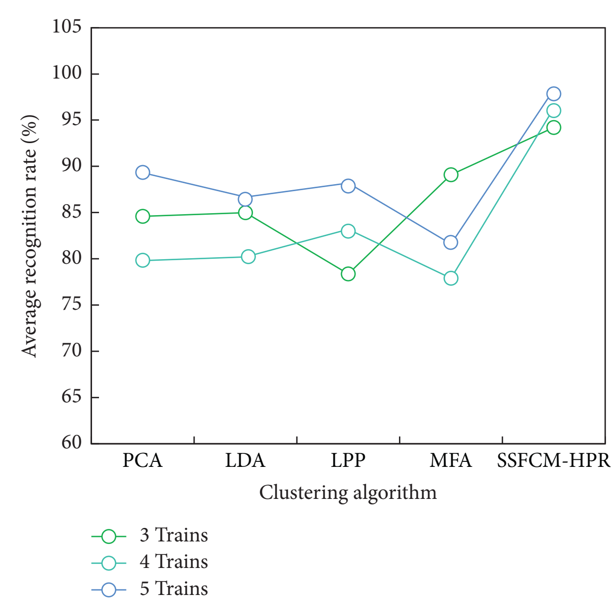

FIGURE 6: Average recognition rate of various algorithms on the ORL database.

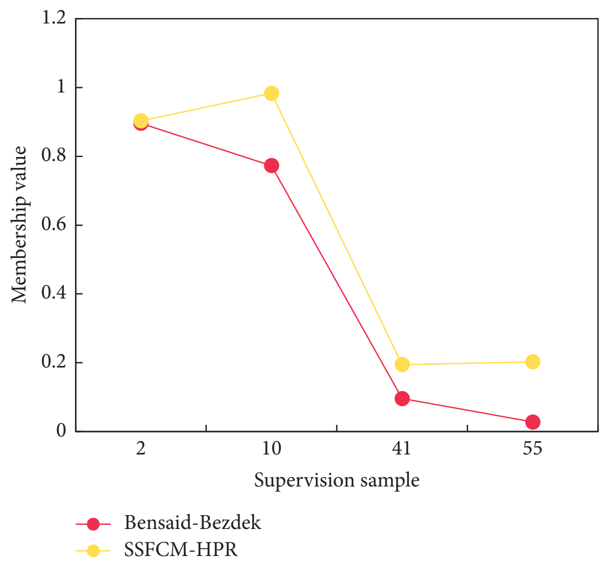

Figure 7: Comparison of weights and membership values of supervised samples by each algorithm.

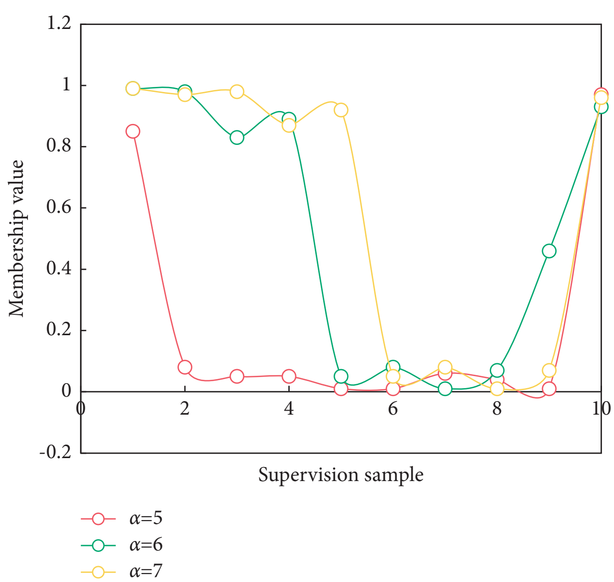

Figure 8: Dividing value of the membership degree of each sample.

weight of unsupervised samples increases as the value increase, weakening the guiding role of supervised samples in the clustering process.

4.3. The Analysis of FCM-UserCF Algorithm. This paper devised a performance test experiment to determine the efficacy of the FCM-UserCF algorithm. The experimental dataset for this study is MovieLens. The data come from a nonprofit research-oriented web recommendation system website. The dataset has two main components: a large number of users and a large number of movies, and the users' movie rating data are sufficient. The experimental dataset includes a training dataset and a test dataset, similar to other types of machine learning datasets. The training set-to-test set

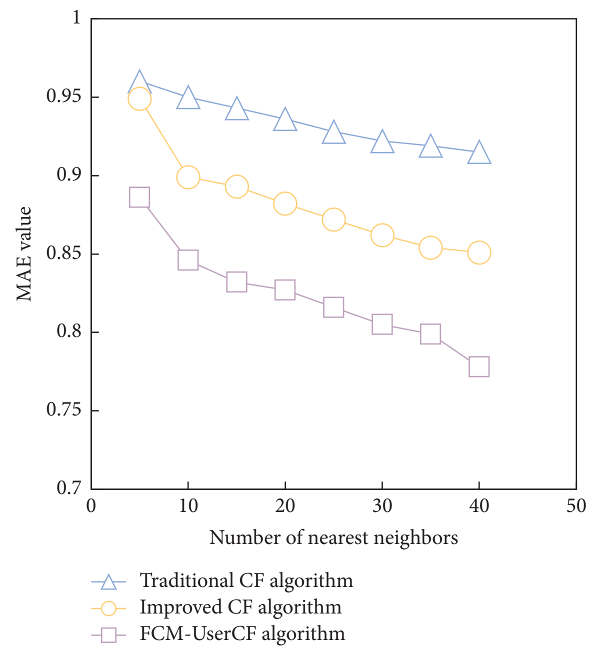

Figure 9: Comparison of algorithm effects.

ratio is 8 : 2. The MAE (mean absolute error) experiment is used to assess the algorithm's effectiveness. The MAE value is inversely proportional to the recommendation quality because it is the average of the absolute values of errors between all individual user ratings and real ratings.

Comparing the parallel FCM-UserCF algorithm, the improved CF algorithm proposed in [20], and the traditional CF algorithm, when calculating the average absolute error value, the number of nearest neighbors takes 5 as the starting value and increases to 30 at intervals of 5. Figure 9 compares the effects of the algorithms.

In this paper, considering that users with similar backgrounds are more likely to have similar tastes in life, FC is carried out according to user background information, and similarity calculation is carried out among users with similar backgrounds. Moreover, the Slope One algorithm is used to fill the missing data before CF, which is conducive to better selecting the nearest neighbor, thus improving the accuracy of recommendation.

In this paper, experiments are carried out with different scales of data, and the time consumption of parallelizing FCM-UserCF algorithm and serializing FCM-UserCF algorithm under different scales of data is compared. The calculation time of the data scale from 50,000 to 300,000 is shown in Figure 10.

Serialized FCM-UserCF algorithm is more time-consuming than parallelized FCM-UserCF algorithm, which is due to the large memory consumption in FC and similarity matrix calculation, and such intensive calculation is also the shortcoming of the CPU.

In contrast, the parallelized FCM-UserCF algorithm adopts a distributed form when dealing with large amounts of data, and each node calculates at the same time, splitting and merging big data, which also fully embodies the advantages of parallel calculation of master-slave nodes.

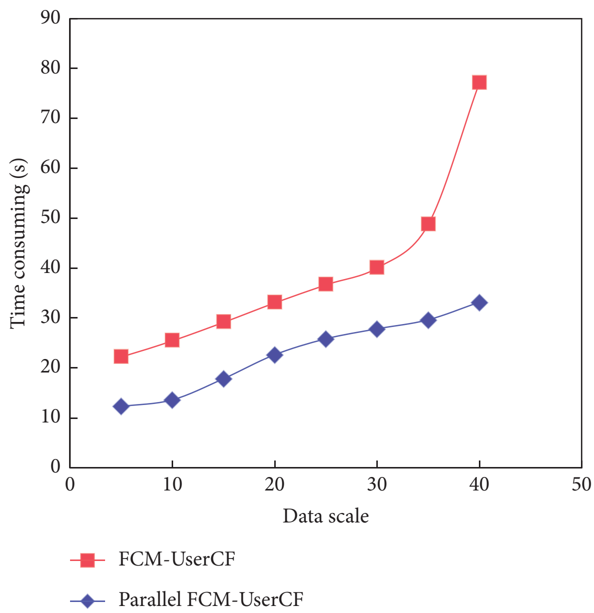

FIGURE 10: Time consumption comparison.

5. Conclusion

The preservation and transmission of concrete material culture, as well as the preservation and transmission of its cultural subject and lifestyle, are all part of the reconstruction of local culture. Art's role in rural revitalization offers distinct benefits in terms of creation design, ingenuity culture, cultural preservation and dissemination, and so on. This paper introduces a novel SSFCM-HPR algorithm. This algorithm not only preserves the fuzziness of supervised sample division but also better reflects the clustering process's guiding role of various supervised samples. It should be treated with FCM-UserCF. The analysis of system requirements, the design of the system architecture and functions, and the design of the database are all completed. The system interface's realization effect is shown, and the function test is completed. The test results demonstrate that the work presented in this paper is practical. Recognize the value and importance of rural culture in the development of urbanization and modernization, and use proper protection and inheritance methods to ensure that rural revitalization continues to progress and live forever.

The implementation mechanism, personnel organization structure, and funding sources required by art intervention in rural planning and design were not discussed in depth in this study. As a result, the study's main findings must be continuously practiced and verified in the future.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares no conflicts of interest.

Acknowledgments

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Research Article

A Horizontal Competition-Cooperation Game of Technological Innovation in an Automobile Cluster Supply Chain

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The horizontal competition-cooperation game of technological innovation in a two-stage automobile cluster supply chain composed of a duopoly of automobile manufacturers and a single automobile dealer is studied. The four game models are constructed based on the relationship of horizontal competition cooperation between automobile manufacturers and research and development (R&D) mode, and each game model gives the optimal price decision and optimal technical content decision of new products when the automobile manufacturer and automobile dealer maximise their profits. By comparing the equilibrium results of each game model and conducting numerical simulation analysis, we reveal the effects of the competition-cooperation relationship and R&D mode on supply chain decision-making. The results show the following: (1) A fully cooperative innovation strategy can maximise the total profit of automobile manufacturers, but it will reduce the profit of the automobile dealer. (2) When the horizontal competition is not fierce and the consumption preference for technical content is weak, innovation strategy of competition cooperation (competition but cooperative R&D) can enable the automobile dealer to obtain the maximum profit. (3) Market preference for the technological content of automotive products accrues greater potential benefits to the whole supply chain channel.

1. Introduction

In the contemporary knowledge economy and information revolution, technological innovation has become a key factor in enterprise development. That enterprises improve the technical content of new products through R&D activities is an inevitable choice for improving supply chain game capabilities. Under the background of increased homogenisation of automobile products, technological innovation is also driver of development in such enterprises; therefore, automotive enterprises must continuously engage in technological innovation to improve the competitiveness of the industry. The cluster mode of a supply chain can induce more convenient conditions for technological innovation in the automobile industry. In the operational environment of the cluster supply chain, an atmosphere of competition and cooperation prevails: supply chain members adopt cooperative innovation to cope with environmental pressure, but they will also compete in the final product market for the maximisation of their own interests; for example, GAC and SAIC jointly develop core technologies but compete in the final product market. Automobile enterprises conduct horizontal cooperation in R&D of key technologies to stimulate market demand, creating large economic and synergistic benefits. Obviously, the problem of choosing technological innovation strategies in automobile cluster supply chain is essentially a game problem that constantly meets and stimulates consumer demand to seek the equilibrium of interests, and the competition-cooperation game of supply chain members and the choice of R&D mode have an important influence on the solution of the above problem. This paper mainly provides a reasonable solution path for the coordination of the interests of all parties in the game, and also provides theoretical basis and technical support for automobile enterprise managers to boost profit and innovate management decisions, so as to improve the competitiveness of our country's automobile industry clusters.

The remainder of this paper is organized as follows: Section 2 introduces related work. Section 3 raises research question and makes model assumptions. Section 4 constructs four game models of technological innovation and proposes the equilibrium strategy in different game situations. The analysis of calculation examples and numerical simulation is discussed in Section 5. Finally, Section 6 summarises the paper.

2. Related Work

At present, the research into supply chain technological innovation is relatively abundant, but it mainly focuses on vertical cooperation and seldom studies from the perspective of competition cooperation, and it involves less research on competition and cooperation game in the automotive supply chain. The research on the cooperative innovation of supply chain mainly focuses on the importance of cooperation, cooperation model, mode selection, benefit distribution, and so on. In terms of the importance, Du et al. [1] analysed the importance of cooperative investment contract between suppliers and manufacturers to sustainable innovation through a Stackelberg Game model. Lu et al. [2] studied the technological innovation decision-making problem of the supply chain by using the method of competition and cooperation. The fundamental motivation for enterprises to participate in technological innovation cooperation is to obtain more benefits from the cooperation. Therefore, the distribution of benefits in cooperative innovation has attracted the attention of scholars. Yoon and Jeong [3]explored the problem of maximising personal profits and total profits in the reverse supply chain from the perspective of profit distribution. Zhang [4] used the Shapley value method to propose a reasonable income distribution system for collaborative innovation in the supply chain. In terms of mode selection, Wang [5] studied the selection of vertical technological innovation mode of new products in the supply chain. Mu et al. [6] studied technological innovation in a two-stage supply chain on an e-commerce sales channel under different cooperation modes. Wei and Wang [7] used differential game methods to analyse the technological innovation of manufacturers and suppliers in terms of carbon emission reduction. The above studies have studied the longitudinal technological innovation of the supply chain from different aspects, but the research on the technological innovation from the perspective of the automotive industry is still insufficient. Most scholars' research on technological innovation of automotive supply chain focuses on its influencing factors and internal mechanisms and mainly adopts methodologies such as system dynamics and game theory. For example, Li et al. [8] used system dynamics to analyse the influencing factors of the technological innovation capability of the automobile industry. Li et al. [9] used a three-stage dynamic game model to explore the relationship between technology diffusion, innovation performance, and technology research and development in the automotive industry. Deng [10] used game theory to explore the internal mechanism of technological innovation in the automobile industry cluster. Li et al. [11] established an evolutionary game model of cooperative innovation between automobile manufacturer and battery company. It can be seen that the research on the technological innovation of the automotive supply chain seldom explores the horizontal game of technological innovation cooperation between manufacturers, and the research on the competition-cooperation relationship between enterprises is relatively lacking.

Research on horizontal competition-cooperation games involving technological innovation in supply chains mainly focuses on price and production competition, but it rarely considers the technical content of new products. Liu and Feng [12] studied "Price–Greenness" competition in a horizontal competitive game. Seyedhosseini et al. [13] proposed a new competitive demand that is price dependent for a two-stage competitive supply chain composed of a monopoly manufacturer and two duopoly retailers. Hong and Naihan [14] discussed the production and price decisions of two logistics suppliers by using the Cournot competitive model and the Bertrand competition model. Li et al. [15] built two price game models of horizontal recyclers. Mai et al. [16] constructed a dynamic Cournot model based on price competition for duopoly manufacturers. A few scholars have considered the influence of technical content of products. For example, Hu et al. [17] analysed the game problem regarding optimal technical content of duopoly enterprises with heterogeneous products. Chu [18] assessed the impact of technical content of product on channel decision by using game theory, but he focused on the improvement mechanism of technical content of product and seldom considered the combined effect of price and technical output of the product. The above research mainly discusses the horizontal competition and cooperation game problem from the aspects of price competition, green degree competition, output competition, etc. However, the research involving "price-technology content of new product" competition is still insufficient.

In summary, scholars' research on technological innovation of supply chain mostly considers vertical cooperation, production competition, and price competition; however, it does not involve competition in terms of the technical content of new products. In addition, a few studies take the automobile industry as an example to study the horizontal competition-cooperation game of technological innovation. In view of the deficiencies in the existing literature, we discuss the game equilibrium strategy of profit maximisation between two automobile manufacturers and automobile dealer in the process of horizontal competition cooperation in technological innovation under different cases from the perspective of balance of interests. It provides some theoretical support for the stakeholders along the automotive supply chain to meet the market demand and seek the balance of interests in the horizontal competition-cooperation game of technological innovation.

3. Problem Description and Assumption

3.1. Description. We studied the horizontal competition-cooperation game of technological innovation in the two-stage supply chain of automobile industry cluster composed of a duopoly of automobile manufacturers $M_i\,(i = 1, 2)$ and a single automobile dealer R. Two automobile manufacturers produce homogeneous but alternative products, which are different in terms of technical content due to their different levels of technological innovation. Since the horizontal cooperation mode is a form of joint participation in technological innovation and cooperation for enterprises in the same industry [19], therefore, whole automobile manufacturers can develop new products through technological innovation to promote the realisation of the market for new products. Automobile manufacturers sell products to an automobile dealer at price ω_i, and then the automobile dealer sells products to the consumer at price p_i; lastly, consumers determine the demand for product i according to its price ω_i, p_i, and technical content t_i. The process is displayed in Figure 1.

In this supply chain model, there is horizontal competition cooperation between two automobile manufacturers. In horizontal competition, two automobile manufacturers pursue maximisation of their own interests. Two automobile manufacturers pursue maximisation of overall income in horizontal cooperation. Meanwhile, there are two modes of R&D: cooperative and independent.

Consumers have demand preference when buying technologically innovative products, and they have higher rigid demand for products with high technical content. Both products have different technical contents because of the difference in technological innovation ability of enterprises, and consumers exactly perceive the difference of products through the difference in technical content of products; therefore, enterprises can affect consumer demand preference for products according to p_i and t_i. In addition, the high similarity of new products developed jointly leads to the reduction of consumer perception of the difference between the two products and the increase of substitutability. Therefore, the competition between products is more intense. The four game equilibrium strategies are developed based on the horizontal competition-cooperation relationship and R&D mode between two automobile manufacturers (Figure 2).

In Figure 2, OL is an Innovation Strategy of Pure Competition and CJ is an Innovation Strategy of Full Cooperation. CL and OJ are Innovation Strategies of Competition Cooperation, they indicate that there is a cooperative relationship between the two automobile manufacturers but independent R&D, or there is a competitive relationship between the two automobile manufacturers but cooperative R&D.

3.2. Symbol Description. The meaning of each variable of the game model is shown in Table 1.

3.3. Supplementary Premise

Assumption 1. In the automotive cluster supply chain, there are two dominant automobile manufacturers upstream in a duopoly market that has similar technological strength and equal status; there is a big $M_i\,(i = 1, 2)$ automobile dealer R downstream. The two manufacturers cooperate in technological innovation to develop and produce new products which will be sold to the automobile dealer at price ω_i.

Assumption 2. The parameter $\lambda\,(0 < \lambda < 1)$ is the degree of product substitution, namely, competition intensity. It reflects the substitution effect of another product when the price of one product changes, $\lambda \longrightarrow 0$ indicates that the products are irreplaceable, and $\lambda \longrightarrow 1$ indicates that the products are completely replaceable. At the same time, the larger λ, the more intense the competition between two automobile manufacturers.

Assumption 3. The production cost of M_i can be reduced after technological innovation, and the amount of cost reduction x_i can also represent the level of technological innovation; $\beta_i = 1$ refers to coefficient of technology spillover between two enterprises, which is affected by some factors such as knowledge transmission ability and communication ability between supply chain enterprises. Under normal circumstances, $\beta \in [0, 1]$, and $\beta = 1$ when the two parties cooperate in R&D, because the enterprise will unreservedly contribute its own technological know-how to cooperative innovation. The marginal cost of production of M_i can be expressed as $c_i = c_{M_i} - x_i - \beta x_j$, $c_{M_i} > x_i + \beta x_j$, $i,\ j = 1, 2$.

Assumption 4. The technical content of the two products is $t_i\,(t_i > 0)$. There is a diminishing effect of marginal return on R&D investment of new products, so it can be written as $I_i = (1/2)t_i^2$. In the case of independent R&D, all R&D costs shall be borne by M_1 and M_2 alone; in the case of cooperative R&D, the two enterprises jointly discuss the total investment of innovation which is $I_i = (1/2)t_0^2$, the share borne by M_1 is θ, and the share borne by M_2 is $(1 - \theta)$.

3.4. Demand Function Construction. Technological innovation comes from the pull of market demand, and enterprises seek technological innovation under the guidance of market demand [20]. In terms of model expression, demand function is the extremely important part of enterprise profit structure. The inverse demand function is defined as $p_i = a - q_i - \lambda q_j\,(i, j \in \{1, 2\}, i \neq j)$, where a is the basic market potential. Without loss of generality, when there is competition in price and technical content of new products, the demand function [7] is as follows: $q_j = a - (1/1 - \lambda)p_i + (\lambda/1 - \lambda)\ \ p_j + \mu((1/1 - \lambda)t_i - (\lambda/1 - \lambda)t_j)$, $a > c_1 + c_2$. The two manufacturers can choose to develop either jointly or independently in terms of new key technologies for development of new products. Cooperative R&D can bring about a reduction in differentiation and higher competitive intensity between products. It is assumed that ξ represents the increased competitive extent caused by cooperative R&D, and $0 \leq \xi\lambda < 1$. The demand function is $q_j = a - (1/1 - \xi\lambda)p_i + (\xi\lambda/1 - \xi\lambda)\ \ p_j + \mu((1/1 - \xi\lambda)t_i - (\xi\lambda/1 - \xi\lambda)t_j)$, where $\xi \geq 1$ means that competition is more intense because the difference between products perceived by consumers is reduced.

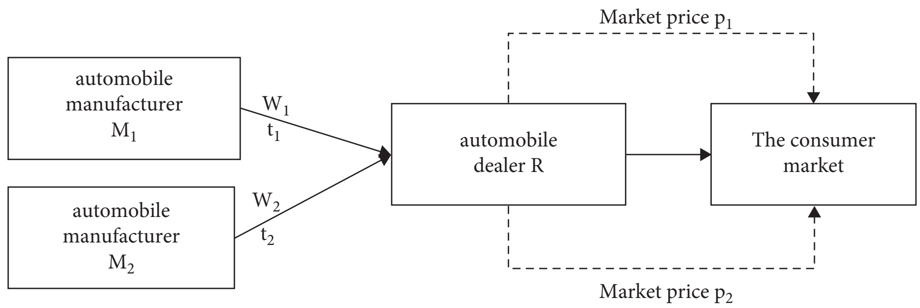

Figure 1: Two-stage supply chain with technological content and price competition of new products.

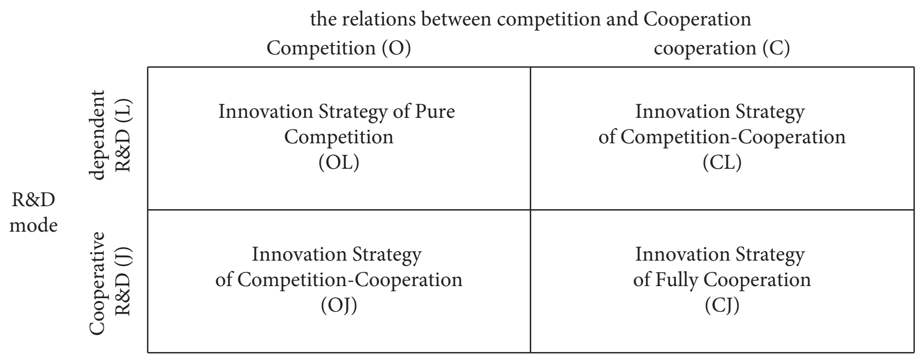

Figure 2: The four game equilibrium strategies.

Table 1: List of symbols.

Symbol	Description
$\mathbf{i}$	Automobile manufacturer product, $i = 1, 2$
λ	Alternative levels of products, namely, competition intensity $(0 < \lambda < 1)$
$\mathbf{c}_{\mathbf{M}_i}$	Production cost of automobile manufacturers
$\mathbf{c}_\mathbf{i}$	The marginal production cost of automobile manufacturers
$\mathbf{I}_\mathbf{i}$	The R&D investment cost of new products
$\mathbf{x}_\mathbf{i}$	The cost reduction caused by technological innovation
$\beta_\mathbf{i}$	Coefficient of technology spillover, $0 < \beta_i < 1$
$\mathbf{t}_\mathbf{i}$	Technical content of product i, $t_i > 0$
$\mathbf{t}_0$	Technical content of new products in cooperation development
θ	Share of R&D investment undertaken by automobile manufacturer M_1
ξ	The increased competitive extent caused by cooperative research and development
μ	The sensitive coefficient of new products' technical content, namely, consumption preference for technical content, $\mu > 0$
$\mathbf{a}$	Basic demand for entire automobile manufacturers, $a > 0$
$\mathbf{q}_\mathbf{i}$	Demand for automobile manufacturers
$\mathbf{p}_\mathbf{i}$	Market price
$\omega_\mathbf{i}$	Wholesale price
$\pi_{\mathbf{M}_i}$	The profit of automobile manufacturer
$\pi_\mathbf{M}^\mathbf{T}$	The total profit of automobile manufacturers
$\pi_\mathbf{R}$	The profit of automobile dealer

4. Construction and Analysis of the Game Model of Technological Innovation

According to the horizontal competition-cooperation relationship and R&D mode between two automobile manufacturers, we constructed four game models of technological innovation.

The four game models of technological innovation, namely, four game equilibrium strategies of technological innovation, are constructed according to the different competition-cooperation relationship and R&D modes of two automobile manufacturers. The game model can be described as the profit expression of each member of the supply chain, which is the marginal profit multiplied by the demand function from which R&D investment in new products is then subtracted. When calculating the profit, the marginal profit is equal to the wholesale price minus the production cost or the market sales price minus the wholesale price; R&D investment in new products is expressed as a quadratic function of technical content of new products; the marginal production cost of automobile manufacturers is calculated by subtracting the reduction of production cost caused by technological innovation from the production cost. The model is solved by backward induction to obtain the equilibrium strategy of each game case, corresponding to the optimal wholesale price, the optimal market price, and the optimal technical content of new products, giving the equilibrium profit of each channel member. To facilitate differentiation, "*" is used herein to represent the best decision.

4.1. Game Equilibrium Strategy of Pure Competitive Innovation (OL). In the OL strategy, two automobile manufacturers have a competitive relationship and independently develop new products. The game rules are such that automobile manufacturers first decide the wholesale price of two products and the technical content of new products based on maximisation of their own profit; then the automobile dealer decides the market price of the two products. The game model is described as follows:

$$\text{S.t.}\begin{cases} \max \pi_{M_1}^{OL} = \left(\omega_1 - \left(c_{M_1} - x_1 - \beta x_2\right)\right)\left(a - \dfrac{p_1^* - \mu t_1}{1-\lambda} + \dfrac{\lambda\left(p_2^* - \mu t_2\right)}{1-\lambda}\right) - \dfrac{1}{2}t_1^2, \\ \max \pi_{M_1}^{OL} = \left(\omega_2 - c_2\right)\left(a - \dfrac{p_2^* - \mu t_2}{1-\lambda} + \dfrac{\lambda\left(p_1^* - \mu t_1\right)}{1-\lambda}\right) - \dfrac{1}{2}t_2^2, \\ \left(p_1^*, p_2^*\right) \text{must meet the following condition}: \\ \max \pi_R^{OL} = \left(p_1 - \omega_1\right)\left(a - \dfrac{p_1 - \mu t_1}{1-\lambda} + \dfrac{\lambda\left(p_2 - \mu t_2\right)}{1-\lambda}\right) \\ +\left(p_2 - \omega_2\right)\left(a - \dfrac{p_2 - \mu t_2}{1-\lambda} + \dfrac{\lambda\left(p_1 - \mu t_1\right)}{1-\lambda}\right). \end{cases} \tag{1}$$

Proposition 1. *In the OL strategy, the optimal wholesale price and the optimal technical content of new products of manufacturers and the optimal market price and the optimal technical content of new products of dealer can be written as*

$$\begin{aligned} \omega_i^{OL^*} &= \frac{a + c_{M_i} - x_i - \beta x_j}{2} + \frac{\mu^2\left(a - c_{M_i} + x_i + \beta x_j\right)}{8 - 2\mu^2}, \\ t_i^{OL^*} &= \frac{\mu\left(a - c_{M_i} + x_i + \beta x_j\right)}{4 - \mu^2}, \\ p_i^{OL^*} &= \frac{3a + c_{M_i} - x_i - \beta x_j}{4} + \frac{3\mu^2\left(a - c_{M_i} + x_i + \beta x_j\right)}{16 - 4\mu^2}. \end{aligned} \tag{2}$$

Proof. By backward induction, we find the market price of automobile dealer when given the wholesale price decision and the technical content of decision $(\omega_1, t_1, \omega_2, t_2)$ of the automobile manufacturers. Firstly, taking the first-order partial derivatives of π_R^{CJ} with respect to p_1 and p_2, respectively, and taking the second-order derivatives, the Hessian matrix is obtained:

$$H = \begin{bmatrix} \dfrac{\partial^2 \pi_R^{OL}}{\partial p_1^2} & \dfrac{\partial^2 \pi_R^{OL}}{\partial p_1 p_2} \\ \dfrac{\partial^2 \pi_R^{OL}}{\partial p_2 p_1} & \dfrac{\partial^2 \pi_R^{OL}}{\partial p_2^2} \end{bmatrix} = \begin{bmatrix} \dfrac{2}{\lambda - 1} & -\dfrac{2\lambda}{\lambda - 1} \\ -\dfrac{2\lambda}{\lambda - 1} & \dfrac{2}{\lambda - 1} \end{bmatrix}. \tag{3}$$

Note that $\partial^2 \pi_R^{OL}/\partial p_1^2 = 2/\lambda - 1 < 0$ when $\begin{vmatrix} 2/\lambda - 1 & -2\lambda/\lambda - 1 \\ -2\lambda/\lambda - 1 & 2/\lambda - 1 \end{vmatrix} = 4(1+\lambda)/1 - \lambda > 0$; π_R^{CJ} is a strictly concave function of p_i, so there is a unique maximal solution. Taking the first-order partial derivative of p_i and setting it to zero gives

$$\begin{cases} a + \dfrac{p_1 - \omega_1}{\lambda - 1} + \dfrac{p_1 - \mu t_1}{\lambda - 1} - \dfrac{\lambda(p_2 - \mu t_2)}{\lambda - 1} - \dfrac{\lambda(p_2 - \omega_2)}{\lambda - 1} = 0, \\ a + \dfrac{p_2 - \omega_2}{\lambda - 1} + \dfrac{p_2 - \mu t_2}{\lambda - 1} - \dfrac{\lambda(p_1 - \mu t_1)}{\lambda - 1} - \dfrac{\lambda(p_1 - \omega_1)}{\lambda - 1} = 0. \end{cases} \tag{4}$$

According to equation (4),

$$\begin{cases} p_1 = \dfrac{\omega_1 + a + \mu t_1}{2}, \\ p_2 = \dfrac{\omega_2 + a + \mu t_2}{2}. \end{cases} \tag{5}$$

Substituting equation (5) into the profit function $\pi_{M_1}^{CJ}$ of automobile manufacturer M_1 gives

$$\pi_{M_1}^{OL}(w_1, t_1) = \left(\omega_1 - \left(c_{M_1} - x_1 - \beta x_2\right)\right)\left(a - \frac{(\omega_1 + a + \mu t_1/2) - \mu t_1}{1 - \lambda} + \frac{(\lambda(\omega_2 + a + \mu t_2)/2) - \mu t_2}{1 - \lambda} - \frac{1}{2}t_1^2.\right. \tag{6}$$

Taking the first-order partial derivatives of $\pi_{M_1}^{OL}(w_1, t_1)$ with respect to ω_1, t_1, respectively, and taking the second-order derivatives, we obtain the Hessian matrix:

$$H = \begin{bmatrix} \dfrac{\partial^2 \pi_{M_1}^{OL}(\omega_1, t_1)}{\partial \omega_1^2} & \dfrac{\partial^2 \pi_{M_1}^{OL}(\omega_1, t_1)}{\partial \omega_1 t_1} \\ \dfrac{\partial^2 \pi_{M_1}^{OL}(\omega_1, t_1)}{\partial t_1 \omega_1} & \dfrac{\partial^2 \pi_{M_1}^{OL}(\omega_1, t_1)}{\partial t_1^2} \end{bmatrix} = \begin{bmatrix} -1 & \dfrac{\mu}{2} \\ \dfrac{\mu}{2} & -1 \end{bmatrix}. \tag{7}$$

Since $(\partial^2 \pi_{M_1}^{OL}(\omega_1, t_1)/\partial \omega_1^2) < 0$ and $\begin{vmatrix} -1 & \mu/2 \\ \mu/2 & -\theta \end{vmatrix} = 1-$ $(\mu^2/4) > 0$, $\pi_{M_1}^{OL}(w_1, t_1)$ is a strictly concave function of ω_1 and t_1. Taking the first derivative of $\partial^2 \pi_{M_1}^{OL}(w_1, t_1)$ with regard to ω_1 and set it to zero, ω_1 can be written as follows:

$$\omega_1(t_1) = \frac{a + c_{M_1} - x_1 - \beta x_2 + \mu t_1}{2}. \tag{8}$$

Substituting equation (8) into equation (6), the profit of manufacturer M_1 is as follows:

$$\pi_{M_1}^{OL}(t_1) = \left(\frac{a + c_{M_1} - x_1 - \beta x_2 + \mu t_1}{2} - \left(c_{M_1} - x_1 - \beta x_2\right)\right)$$
$$\left(a - \frac{\left(\left(\left(a + c_{M_1} - x_1 - \beta x_2 + \mu t_1\right)/2\right) + a + \mu t_1/2\right) - \mu t_1}{1 - \lambda} + \frac{\left(\lambda\left(\left(a + c_{M_1} - x_1 - \beta x_2 + \mu t_2/2\right) + a + \mu t_2\right)/2\right) - \mu t_2}{1 - \lambda} - \frac{1}{2}t_1^2.\right. \tag{9}$$

Setting the first derivative of equation (9) with respect to t_1 to zero, the optimal technical content of the new products is described as

$$t_1^* = \frac{a\mu - \left(c_{M_1} - x_1 - \beta x_2\right)\mu}{-\mu^2 + 4}. \tag{10}$$

Substituting equation (10) into equation (8), the optimal wholesale price can be obtained:

$$\omega_1^* = \frac{a + c_{M_1} - x_1 - \beta x_2}{2} + \frac{\mu^2\left(a - c_{M_1} + x_1 + \beta x_2\right)}{8 - 2\mu^2}. \tag{11}$$

By the same calculation, the optimal wholesale price and technical content of new products of automobile manufacturer M_i are written as follows:

$$\begin{aligned} t_i^{OL^*} &= \frac{\mu\left(a - c_{M_i} + x_i + \beta x_j\right)}{4 - \mu^2}, \\ \omega_i^{OL^*} &= \frac{a + c_{M_i} - x_i - \beta x_j}{2} + \frac{\mu^2\left(a - c_{M_i} + x_i + \beta x_j\right)}{8 - 2\mu^2}, \\ p_i^{OL^*} &= \frac{3a + c_{M_i} - x_i - \beta x_j}{4} + \frac{3\mu^2\left(a - c_{M_i} + x_i + \beta x_j\right)}{16 - 4\mu^2}. \end{aligned} \tag{12}$$

Proposition 1 is proved. □

Inference 1. In the OL strategy, the sensitive coefficient of the technical content of new products is positively correlated with technical content of new products, wholesale price, and market price.

Proof

$$\frac{\partial t_i^{OL^*}}{\partial \mu} = \frac{\left(a - c_{M_i} + x_i + \beta x_j\right)\left(\mu^2 + 4\right)}{\left(\mu^2 - 4\right)^2} > 0,$$
$$\frac{\partial \omega_i^{OL^*}}{\partial \mu} = \frac{\left(a - c_{M_i} + x_i + \beta x_j\right)\left(\mu^3 + 16\mu\right)}{\left(2\mu^2 - 8\right)^2} > 0, \quad (13)$$
$$\frac{\partial p_i^{OL^*}}{\partial \mu} = \frac{96\mu}{\left(4\mu^2 - 16\right)^2} > 0.$$

Inference 1 indicates that the more consumers are sensitive to technical content in new products, the more likely they are to buy high-tech automobile products, which can stimulate automobile manufacturers to improve the technological content of products and also bring about higher wholesale price and market sales price.

The equilibrium profit $\pi_{M_1}^{OL^*}$, $\pi_{M_2}^{OL^*}$ of two automobile manufacturers and the equilibrium profit $\pi_R^{OL^*}$ of automobile dealer can be obtained by Proposition 1 and equation (1). □

4.2. Game Equilibrium Strategy of Competition-Cooperation Innovation (CL). In the CL strategy, the automobile manufacturers enjoy a competitive relationship but cooperate to develop new products. The game rule is such that two automobile manufacturers cooperate in R&D and, respectively, bear the costs thereof. They first set the common technological content t_0 of the two products based on the maximum total revenue, M_1 bears the R&D cost in proportion θ, which is $(1/2)\theta t_0^2$, and M_2 bears the R&D cost in proportion $(1-\theta)$, that is, $(1/2)(1-\theta)t_0^2$. The two automobile manufacturers decide their wholesale price based on their maximum profit; then the automobile dealer decides their market price based on acquiring maximum profit. The game model is described as follows:

$$\text{S.t.}\begin{cases} \max_{t_0}\pi_M^{CL} = \left(\omega_1^* - c_{M_1} + x_1 + \beta x_2\right)\left(\alpha - \dfrac{p_1 - \mu t_0}{1 - \xi\lambda} + \dfrac{\xi\lambda\left(p_2 - \mu t_0\right)}{1 - \xi\lambda}\right) \\ +\left(\omega_1^* - c_{M_1} + x_1 + \beta x_2\right)\left(\alpha - \dfrac{p_2 - \mu t_0}{1 - \xi\lambda} + \dfrac{\xi\lambda\left(p_1 - \mu t_0\right)}{1 - \xi\lambda}\right) - \dfrac{1}{2}t_0^2, \\ \left(\omega_1^*, \omega_2^*\right) \text{ must meet the following condition}: \\ \max_{\omega_1}\pi_{M_1}^{CL} = \left(\omega_1 - c_{M_1} + x_1 + \beta x_2\right)\left(\alpha - \dfrac{p_1^* - \mu t_0}{1 - \xi\lambda} + \dfrac{\xi\lambda\left(p_2^* - \mu t_0\right)}{1 - \xi\lambda}\right) - \dfrac{1}{2}\theta t_0^2, \\ \max_{\omega_2}\pi_{M_2}^{CL} = \left(\omega_2 - c_{M_2} + x_2 + \beta x_1\right)\left(\alpha - \dfrac{p_2^* - \mu t_0}{1 - \xi\lambda} + \dfrac{\xi\lambda\left(p_1^* - \mu t_0\right)}{1 - \xi\lambda}\right) - \dfrac{1}{2}(1-\theta)t_0^2, \\ \left(p_1^*, p_2^*\right) \text{ must meet the following condition}: \\ \max_{p_1,p_2}\pi_R^{CL} = \left(p_1 - \omega_1\right)\left(\alpha - \dfrac{p_1 - \mu t_0}{1 - \xi\lambda} + \dfrac{\xi\lambda\left(p_2 - \mu t_0\right)}{1 - \xi\lambda}\right) + \left(p_2 - \omega_2\right)\left(\alpha - \dfrac{p_2 - \mu t_0}{1 - \xi\lambda} + \dfrac{\xi\lambda\left(p_1 - \mu t_0\right)}{1 - \xi\lambda}\right). \end{cases} \quad (14)$$

Proposition 2. *In the CL strategy, the optimal wholesale price and the optimal technical content of new products of manufacturers and the optimal market price and the optimal technical content of new products of dealer are as follows:*

$$t_0^{CL^*} = \frac{\mu\left(a - c_{M_i} + x_i + \beta x_j\right)(1 - \xi\lambda)}{2\theta(2 - \xi\lambda)^2 - 2\mu^2(1 - \xi\lambda)^2} - \frac{\mu\left(c_{M_1} - x_1 - \beta x_2 + c_{M_2} - x_2 - \beta x_1\right)}{4},$$
$$\omega_i^{CL^*} = \frac{\left(a - c_{M_i} + x_i + \beta x_j\right)(1 - \xi\lambda)}{\theta(2 - \xi\lambda)^2 - \mu^2(1 - \xi\lambda)^2}, \quad (15)$$
$$p_i^{OL^*} = \frac{2a - \mu\left(c_1 + c_2\right)}{4} + \frac{\left(a - c_i\right)(1 - \xi\lambda)(1 + \mu)}{2\theta(2 - \xi\lambda)^2 - 2\mu^2(1 - \xi\lambda)^2}.$$

Proposition 2 can be proved by backward induction in a manner similar to Proposition 1.

The equilibrium profits $\pi_{M_1}^{CL^*}$ and $\pi_{M_2}^{CL^*}$ of two automobile manufacturers and the equilibrium profit $\pi_R^{CL^*}$ of automobile dealer can be obtained by the combination of Proposition 2 and equation (13).

Inference 2. In the CL strategy, the improvement of technical content of new products is conducive to the increase of total profit earned by the automobile manufacturers.

Proof. Based on the above conclusions, the partial derivative of the total profit of automobile manufacturer on the technical content of new products can be obtained:

$$\frac{\partial \pi_{M_1}^{CL^*}}{\partial t_0} > 0, \quad \frac{\partial \pi_{M_2}^{CL^*}}{\partial t_0} > 0. \tag{16}$$

Inference 2 indicates that the technical content of new products must be improved to maximise the total profit of automobile manufacturers. This is mainly because increasing the technical content of new products can bring about higher wholesale price and stimulate market demand, which will lead to more profits. On the one hand, the improvement of technical content requires more R&D investment costs, manufacturers' assembly costs are also higher, so the wholesale price is higher; on the other hand, consumers have a demand preference for high-tech products. The higher the technical content of the product is, the more it will be favoured by consumers, and the market demand for a product is greater under the influence of the relationship of supply and demand. □

4.3. Game Equilibrium Strategy of Competition-Cooperation Innovation (OJ). The two automobile manufacturers in an OL strategy enjoy a cooperative relationship but independently develop new products. The game rule is such that the two automobile manufacturers decide their respective wholesale price and technical content of new products based on the maximum total revenue accruing to both parties, and then the automobile dealer sets the market sales price of the two products based on its maximum revenue. The game model can be described as follows:

$$\text{S.t.} = \begin{cases} \max_{t_1,\omega_1,t_2,\omega_2} \pi_M^{0j} = \left(\omega_1 - c_{M_1} + x_1 + \beta x_2\right)\left(\alpha - \dfrac{p_1^* - \mu t_1}{1-\lambda} + \dfrac{\lambda(p_2^* - \mu t_2)}{1-\lambda}\right)\dfrac{t_1^2}{2} \\ + \left(\omega_2 - c_{M_2} + x_2 + \beta x_1\right)\left(\alpha - \dfrac{p_2^* - \mu t_2}{1-\lambda} + \dfrac{\lambda(p_1^* - \mu t_1)}{1-\lambda}\right) - \dfrac{t_2^2}{2}, \\ (p_1^*, p_2^*) \text{ must meet the following condition :} \\ \max_{p_1,p_2} \pi_M^{0j} = (p_1, p_1)\left(\alpha - \dfrac{p_1 - \mu t_1}{1-\lambda} + \dfrac{\lambda(p_2 - \mu t_2)}{1-\lambda}\right) \\ + (p_2, p_2)\left(\alpha - \dfrac{p_2 - \mu t_2}{1-\lambda} + \dfrac{\lambda(p_1 - \mu t_1)}{1-\lambda}\right), \end{cases} \tag{17}$$

Proposition 3. *In the OJ strategy, the optimal wholesale price and the optimal technical content of new products of manufacturers and the optimal market price and the optimal technical content of new products of dealer are as follows:*

$$\begin{aligned} t_i^{OJ^*} &= -\frac{\mu\left(a - c_{M_i} + x_i + \beta x_j\right)(1+\lambda)}{\mu^2 + \lambda\mu^2 - 4}, \\ \omega_i^{OJ^*} &= \frac{a + c_{M_i} - x_i - \beta x_j}{2} - \frac{\mu^2\left(a - c_{M_i} + x_i + \beta x_j\right)(1+\lambda)}{2\left(\mu^2 + \mu^2\lambda - 4\right)}, \\ p^{OJ^*} &= \frac{3a + c_{M_i} - x_i - \beta x_j}{4} - \frac{3\mu^2\left(a - c_{M_i} + x_i + \beta x_j\right)(1+\lambda)}{4}. \end{aligned} \tag{18}$$

Proposition 3 can be proved by backward induction in a manner similar to Proposition 1.

Inference 3. In OJ strategy, the inhibitory effect of competitive intensity on wholesale price is greater than that on market price.

Proof. Since $\partial\omega^{OJ^*}/\partial\lambda = ((-\mu^2\, a - c_{M_i} + x_i + \beta x_j t(\lambda + 1)n - q\ \ \mu^2 h(a - c_{M_i} + x_i + \beta x_j)(\lambda\mu^2 + \mu^2 - 4)/2) < 0$, $\partial p^{OJ^*}/\partial\lambda = ((-3\mu^2(a - c_{M_i} + x_i + \beta x_j))/4) < 0$, so competitive intensity has a restraining effect on wholesale price and market price. At the same time, $(\partial\omega^{OJ^*}/\partial\lambda) - (\partial p^{OJ^*}/\partial\lambda) = (u^2(a - c_i)[3 - 2(\lambda\mu^2 + \mu^2 - 4) - 2\mu^2(\lambda + 1)]/4) > 0$ when $0 < \lambda < 1$, we can obtain $(\partial\omega^{OJ^*}/\partial\lambda) - (\partial p^{OJ^*}/\partial\lambda) > 0$; thus, inference 3 is proved.

Inference 3 shows that the wholesale price and market price will decrease with the increase of competitive intensity in the OJ strategy. Therefore, the two automobile manufacturers should take measures to reduce the competitive intensity between them to alleviate the overall loss of profit caused by intensified competition.

Combining Proposition 3 and equation (16), the equilibrium profit $\pi_{M_1}^{OJ^*}$ and $\pi_{M_2}^{OJ^*}$ of two automobile manufacturers and the equilibrium profit $\pi_R^{OJ^*}$ of automobile dealer can be obtained. □

4.4. Game Equilibrium Strategy of Fully Cooperative Innovation (CJ). In the CJ strategy, two automobile manufacturers enjoy a cooperative relationship and cooperate to develop new products. The game rule is such that the two automobile manufacturers share the R&D costs of new products. First, the common technical content t_0 and their respective wholesales are determined based on the maximum total revenue of both parties, and then the automobile dealer determines the market selling price of new products based on their own profits. The game model is described as follows:

$$\text{S.t.}\begin{cases} \max_{t_0}\pi_M^{CL} = \left(\omega_1^* - \left(c_{M_1} + x_1 + \beta x_2\right)\right)\left(\alpha - \dfrac{p_1 - \mu t_0}{1-\xi\lambda} + \dfrac{\xi\lambda\left(p_2 - \mu t_0\right)}{1-\xi\lambda}\right) \\ +\left(\omega_2^* - \left(c_{M_2} + x_2 + \beta x_1\right)\right)\left(\alpha - \dfrac{p_2 - \mu t_0}{1-\xi\lambda} + \dfrac{\xi\lambda\left(p_1 - \mu t_0\right)}{1-\xi\lambda}\right) - \dfrac{t_0^2}{2}, \\ \left(\omega_1^*, \omega_2^*\right) \text{ must meet the following condition}: \\ \max_{\omega_1,\omega_2}\pi_{M_1}^{CL} = \left(\omega_1 - \left(c_{M_1} + x_1 + \beta x_2\right)\right)\left(\alpha - \dfrac{p_1^* - \mu t_0}{1-\xi\lambda} + \dfrac{\xi\lambda\left(p_2^* - \mu t_0\right)}{1-\xi\lambda}\right) \\ +\left(\omega_2^* - \left(c_{M_2} + x_2 + \beta x_1\right)\right)\left(\alpha - \dfrac{p_2^* - \mu t_0}{1-\xi\lambda} + \dfrac{\xi\lambda\left(p_1^* - \mu t_0\right)}{1-\xi\lambda}\right) - \dfrac{t_0^2}{2}, \\ \left(p_1^*, p_2^*\right) \text{ must meet the following condition}: \\ \max_{p_1,p_2}\pi_R^{CL} = \left(p_1 - \omega_1\right)\left(\alpha - \dfrac{p_1 - \mu t_0}{1-\xi\lambda} + \dfrac{\xi\lambda\left(p_2 - \mu t_0\right)}{1-\xi\lambda}\right) + \left(p_2 - \omega_2\right)\left(\alpha - \dfrac{p_2 - \mu t_0}{1-\xi\lambda} + \dfrac{\xi\lambda\left(p_1 - \mu t_0\right)}{1-\xi\lambda}\right). \end{cases} \tag{19}$$

Proposition 4. *In the CJ strategy, the optimal wholesale price and the optimal technical content of new products of manufacturers and the optimal market price and the optimal technical content of new products of dealer are as follows:*

$$\begin{aligned} t_0^{CJ^*} &= \frac{\mu\left(c_{M_1} - x_1 - \beta x_2 + c_{M_2} - x_2 - \beta x_1\right)}{2}, \\ \omega_i^{CJ^*} &= \frac{a + c_{M_i} - x_i - \beta x_j}{2} - \frac{\mu^2\left(c_{M_1} - x_1 - \beta x_2 + c_{M_2} - x_2 - \beta x_1\right)}{4}, \\ p_i^{CJ^*} &= \frac{3a + c_{M_i} - x_i - \beta x_j}{4} - \frac{3\mu^2\left(c_{M_1} - x_1 - \beta x_2 + c_{M_2} - x_2 - \beta x_1\right)}{8}. \end{aligned} \tag{20}$$

By backward induction, the proof of Proposition 4 is akin to that of Proposition 1.

Inference 4. The demand of automobile manufacturers will increase with the technical content of new products.

Proof

$$q^{CJ} = a - \frac{1}{1-\lambda}p_i^{CJ} + \frac{\lambda}{1-\lambda}p_j^{CJ} + \mu\left(\frac{1}{1-\lambda}t_i^{CJ} + \frac{\lambda}{1-\lambda}t_j^{CJ}\right),$$

$$\frac{\partial q_i^{CJ}}{\partial t_i} = \frac{\mu}{(1-\lambda)} > 0,$$

$$\frac{\partial q_i^{CJ}}{\partial t_j} = \frac{\lambda}{1-\lambda} > 0. \tag{21}$$

Inference 4 implies that the technical content of new products is positively correlated with consumer demand preference. Consumers perceive the difference of products by the technical content of products and tend to buy automobile products with high technical content at an acceptable price, so automobile manufacturers can increase consumer demand by improving the technical content of their new products.

Combining Proposition 4 and equation (18), the equilibrium profit $\pi_M^{CJ^*}$, $\pi_{M_2}^{CJ^*}$ of two automobile manufacturers and the equilibrium profit $\pi_R^{CJ^*}$ of automobile dealer can be obtained by solving the equation. □

4.5. Comparative Analysis of the Equilibrium Results of the Game of Technological Innovation

Proposition 5. *Comparing the technical content of new products under the equilibrium state of different games, we can see as follows:* $(1) t_i^{OJ} > t_i^{OL} > t_0^{CJ}$\ *and* $(2) t_0^{CL} > t_0^{CJ}$.

Proof. $t_i^{OL} - t_0^{CJ} = ((\mu\ (a-c_i))/(4-\mu^2)) + ((\mu(c_1 + c_2))/2) > 0$, namely, $t_i^{OL} > t_i^{CJ} t_i^{OL} - t_i^{OJ} = ((\mu(a-c_i))/(4-\mu^2)) - ((\mu(a-c_i)\ (1+\lambda))/(4-\mu^2-\lambda\mu^2)) > 0$, namely, $t_i^{OL} > t_i^{OJ}$; $t_i^{CL} - t_i^{CJ} = ((\mu(a-c_i)(1-\xi\lambda)))/\ (2\theta(2-\xi\lambda)^2 - 2\mu^2(1-\xi\lambda)^2) + (\mu(c_1+c_2))/4 > 0$, namely, $t_i^{CL} > t_i^{CJ}$.

In the same way, other inequalities can be proved. From Proposition 5, we can see that for the technical content of new products, OJ is greater than OL and CJ, and CL is bigger than CJ. This is because the competition and cooperation environment is more conducive to stimulating enthusiasm towards R&D between horizontal enterprises, thus continuously improving the efficiency of R&D and the technical level of new products. In addition, due to consumer preference for technological content, enterprises will also be forced to improve their core competitiveness by improving the technical content of new products in independent R&D to win greater market share. □

Proposition 6. *Comparing the wholesale price decision in the equilibrium state of different games, it can be known that* $(1) \omega_i^{OJ} > \omega_i^{OL}$ *and* $(2) \omega_i^{CJ} > \omega_i^{OL} > \omega_i^{CL}$.

Proof. $\omega_i^{OL} - \omega_i^{OJ} = (\mu^2(a-c_i))/(8-2\mu^2) - ((\mu^2\ (a-c_i)(1+\lambda)))/(8-2\mu^2-2\lambda\mu^2) < 0$, namely, $\omega_i^{OJ} > \omega_i^{OL}$; $\omega_i^{CJ} - \omega_i^{CL} = ((6a + 2c_i + 3\mu^2(c_1+c_2))/8) + ((a-c_1)(1-\xi\lambda)/\theta(2-\xi\lambda)^2 - \mu^2(1-\xi\lambda)^2) > 0$, namely, $\omega_i^{CJ} > \omega_i^{CL}$.

Similarly, other inequalities can be proved. According to Proposition 6, the game equilibrium strategy of fully cooperative innovation can allow the two automobile manufacturers obtain higher wholesale price. The wholesale price of OJ is higher than that of OL, indicating that the cooperative relationship can result in a higher wholesale price than the competitive relationship when two automobile manufacturers undertake independent R&D, because in a competitive environment, companies tend to adopt low-price strategies to win a greater market share. □

Proposition 7. *Comparing the market price decision under the equilibrium state of different games, we find that* $(1) p_i^{CJ} > p_i^{CL}, p_i^{OJ}, p_i^{OL}$ *and* $(2) p_i^{OL} > p_i^{OJ}$.

Proof. $p_i^{CJ} - p_i^{OJ} = (3\mu^2(a-c_i)(1+\lambda)/4) - (3\mu^2\ (c_1+c_2)/8) > (3a+c_i/4) - (3a+c_i/4) = 0$, namely, $p_i^{CJ} > p_i^{OJ}$; $p_i^{OL} - p_i^{OJ} = (3\mu^2(a-c_i)/\ 16-4\mu^2) + (3\mu^2(a-c_i)(1+\lambda)/4) > 0$, namely, $p_i^{OL} > p_i^{OJ}$. Other inequalities can be proved in the same way. According to Proposition 7, the game equilibrium strategy of fully cooperative innovation results in the highest market price, because a cooperative relationship weakens price competition, and joint R&D can yield higher technical content in new products; thus, the automobile dealer can obtain a higher market sales price than when in a competitive relationship.

Considering the complexity of game model, it is difficult to compare the total profit of an automobile manufacturer and the profit of the automobile dealer in different game scenarios through mathematical derivation alone. This study will be conducted using sample calculations and numerical simulation analysis in the following section. □

5. Examples and Numerical Simulation Analysis

The previous content describes an analysis of the equilibrium solution of each member in the four game situations: the further to analyse the influence of the main factors influencing the model on the supply chain decision value, we used MATLAB™ software to conduct sample calculations and numerical simulation analysis, thus providing insight into technological innovation cooperation and recommendations for decision-making. The parameters used in this section are established [12] and salient automobile market data:

$$\begin{aligned} \mu &= 0.9, \\ a &= 2, \\ \lambda &= 0.3, \\ \xi &= 2, \\ \theta &= 0.6, \\ \beta &= 0.4, \\ x_i &= 0.4, \\ c_{M_1} &= 0.5, \\ c_{M_2} &= 0.5. \end{aligned} \tag{22}$$

5.1. Profit Comparison under Different Game Equilibrium Strategies of Technology Innovation. Four types of game equilibrium profits can be obtained by substituting the above parameters into the model, as shown in Table 2.

It can be seen from Table 2 that the game equilibrium strategy of fully cooperative innovation enables two automobile manufacturers to maximise their prices to maximise profits but will damage the interests of automobile dealers. For automobile dealers, CL is better than CJ, and OL is better than OJ, because horizontal competition will stimulate automobile manufacturers to innovate to gain a competitive advantage, thus maximising the profit of the automobile dealer.

5.2. Influence of the Sensitivity Coefficient of New Product Technical Content on the Equilibrium Solution. In this section, we describe analysis of the influence of the sensitivity coefficient of the technical content of new products on wholesale price, market price, total profit accruing to the automobile manufacturers, and those of the automobile dealer (Figures 3–7).

Figure 3 shows that as the sensitivity coefficient of new product technical content increases, the technical content of new product of all strategies increases. When $0 < \mu < 0.8$, CL > OJ > OL > CJ; when $0.8 < \mu < 1.3$, OJ > CJ; therefore, when consumers are not sensitive to the technical content of new products and there is competition between horizontal enterprises, cooperative R&D is better than independent R&D. Independent R&D is better than cooperative R&D when the sensitivity coefficient of the new product's technical content increases and there is a cooperative relationship between horizontal enterprises.

Figure 4 indicates that with the increase in the sensitivity coefficient of new product technical content, the wholesale price will increase under each strategy. When $0 < \mu < 1.15$, CL > OJ > OL > CJ, the game equilibrium strategy of fully cooperative innovation is optimal; when $\mu > 1.15$, OJ > CJ > OL > CL, the game equilibrium strategy of competition-cooperation innovation (collaboration-independent R&D) is optimal.

Figure 5 demonstrates that as the sensitivity coefficient of new product technical content increases, the market price of each strategy also increases. In the case of $0 < \mu < 0.13$, CL > OJ > OL > CJ, cooperation is better than competition; when $\mu > 0.13$, OJ > OL > CJ, competition is better than cooperation.

Figure 6 shows that as the sensitivity coefficient of new product technical content increases, the total profit of the automobile manufacturer in the four game scenarios also increases. When $0 < \mu < 1.2$, OJ > OL > CJ, the game equilibrium strategy of competition-cooperation innovation (competition-cooperative R&D) is optimal; when $\mu > 1.2$, a game equilibrium strategy of pure competitive innovation is optimal.

Figure 7 illustrates that in the four game scenarios, the profit accruing to the automobile dealer increases with the increase of the sensitivity coefficient of new product technical content, and OJ > CL > OL > CJ. When the sensitivity coefficient of new product technical content is low ($0 < \mu < 0.5$), the influences of competition and cooperation relationship and R&D mode on an automobile dealer are not obvious; when the sensitivity coefficient of new product technical content is high ($\mu \geq 0.5$), the influences of

Table 2: Comparison of game equilibrium profit.

Game equilibrium strategy of technology innovation	π_M^{total}	π_R^{total}
OL	20	49.3
CL	33.5	68.5
OJ	43.5	32.2
CJ	55	50

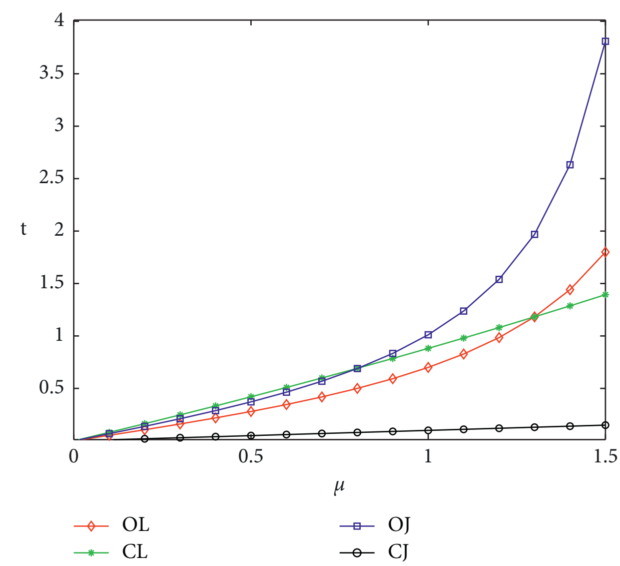

Figure 3: The influence of the sensitivity coefficient of the new product technical content on the new product technical content.

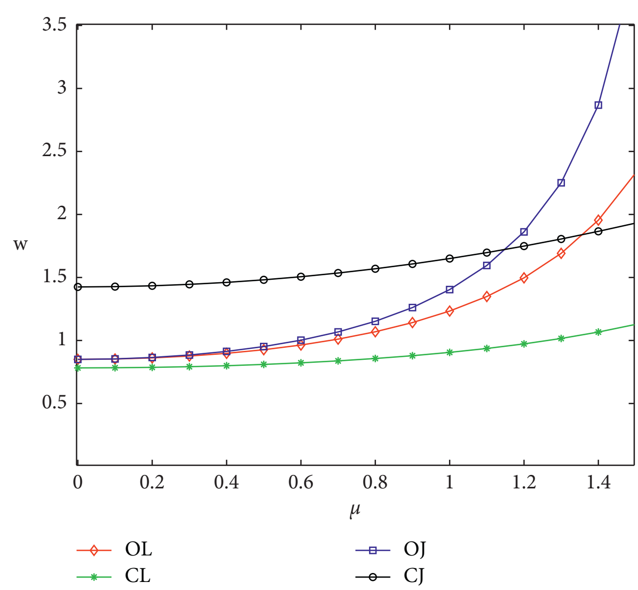

Figure 4: The influence of the sensitivity coefficient of the new product technical content on wholesale price.

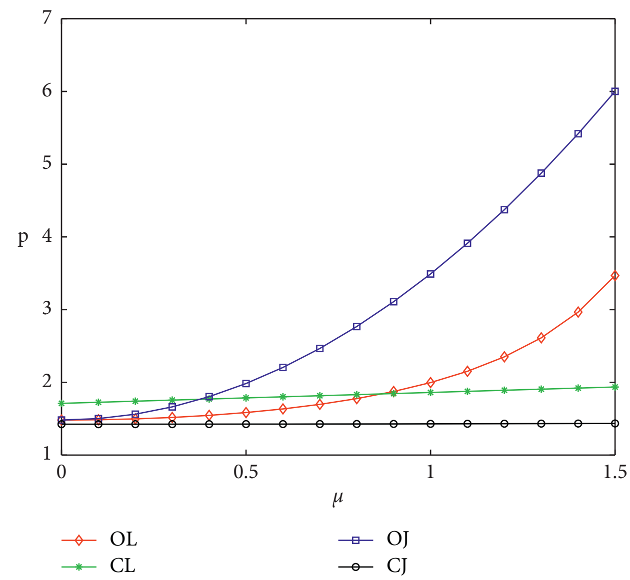

Figure 5: The influence of the sensitivity coefficient of the new product technical content on market sale.

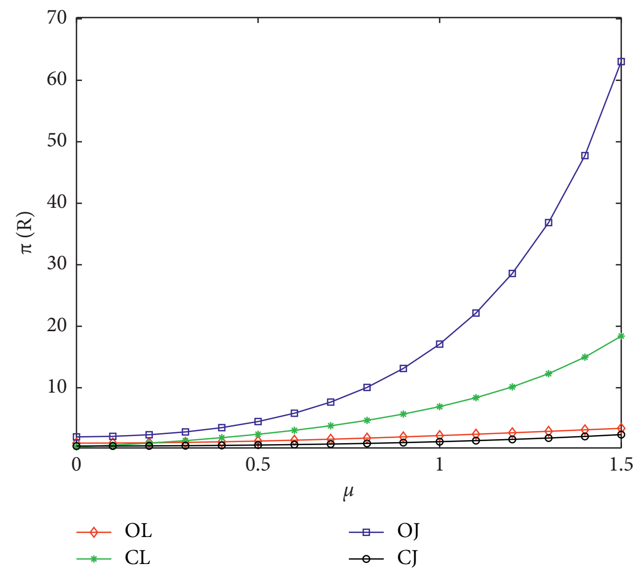

Figure 7: The influence of the sensitivity coefficient of the new product technical content on the profit accruing to the automobile dealer.

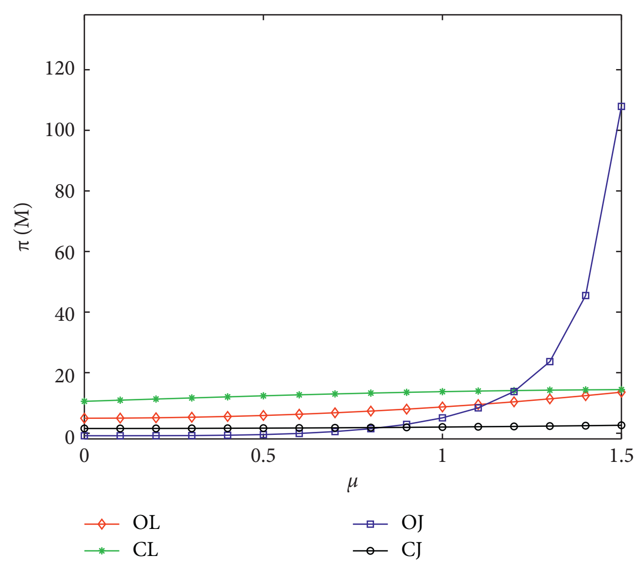

Figure 6: The influence of the sensitivity coefficient of the new product technical content on the total profit of automobile manufacturers.

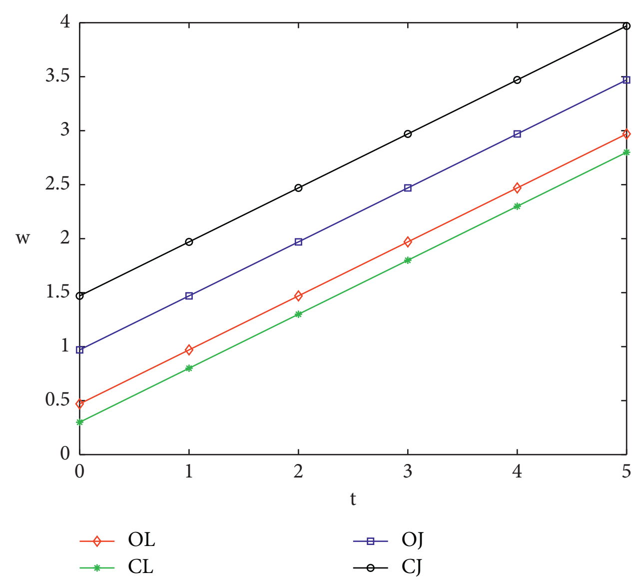

Figure 8: The influence of new product technical content on wholesale price.

competition and cooperation relationship and R&D mode on automobile dealers are evident, and the degree of influence thereof increases with increasing sensitivity coefficient.

5.3. Influence of New Product Technical Content on Equilibrium Solution. Here we describe an analysis of the influence of new product technical content on wholesale prices, market prices, demand, total profit accruing to the automobile manufacturers, and that of the automobile dealer. The results are shown in Figures 8–12.

Figure 8 shows that with the improvement of new product technical content, the wholesale price wholesale price in every game equilibrium strategy also gradually improve, and CJ > OJ > OL > CL. It can be seen that when two companies have a cooperative relationship, cooperative R&D results in a higher wholesale price than independent R&D regardless of changes to the technical content of new products; when there is a competitive relationship between the two companies, independent R&D results in a higher wholesale price than cooperative R&D.

Figure 9 illustrates that the market prices under the four game equilibrium strategies all increase with the increase in the technical content of new products, and the market prices under CJ conditions are significantly higher than when adopting other game strategies. In addition, when $0 < t < 4$,

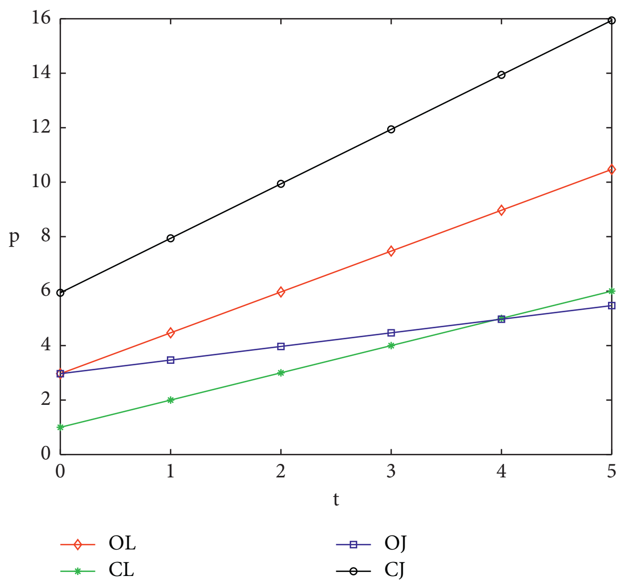

FIGURE 9: The influence of new product technical content on market price.

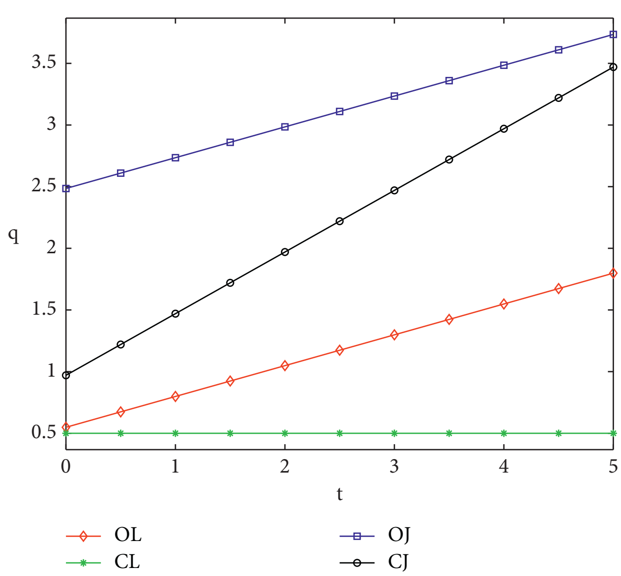

FIGURE 10: The influence of new product technical content on optimal demand.

OJ > CL, cooperation is always better than competition; when $t > 4$, OJ > CL, and competition is better than cooperation.

Figure 10 shows that the technical content of new products is positively correlated with the demand of automobile manufacturers, with OJ > OL and CJ > CL. This shows that a cooperative relationship is always better than a competitive relationship regardless of R&D mode.

Figure 11 depicts that the technical content of new products is also positively correlated with the total profit of the automobile manufacturer, and CJ is the optimal strategy. This indicates that, if automobile manufacturers want to earn a greater total profit, they must improve the technical content of their products.

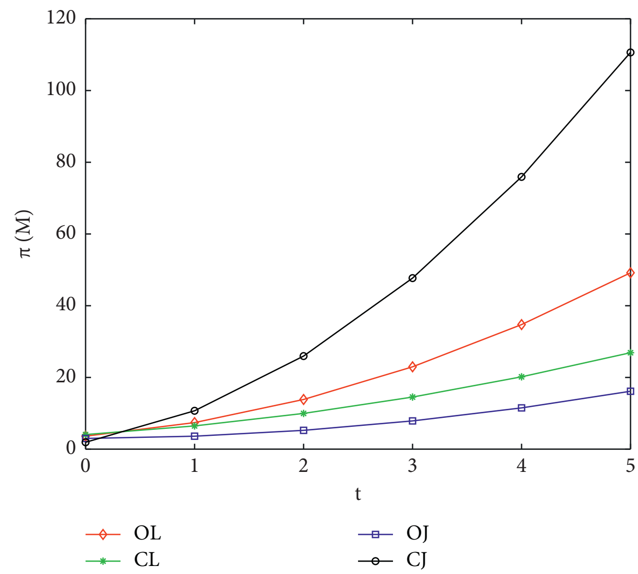

FIGURE 11: The influence of new product technical content on total profit of automobile manufacturers.

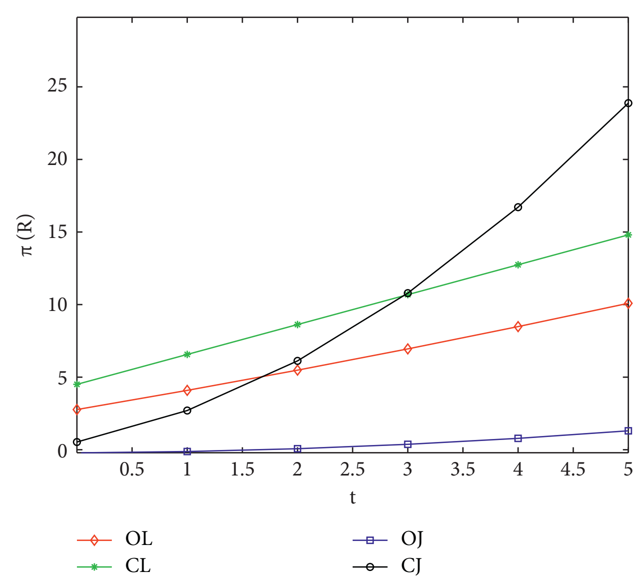

FIGURE 12: Influence of new product technical content on the profit accruing to an automobile dealer.

Figure 12 suggests that the improvement of technical content of the new product can enable automobile dealers to earn greater profits. In addition, when the technical content of the new product is relatively high ($t > 2.96$), the game equilibrium strategy of fully cooperative innovation is much better than the other three game situations.

5.4. Influence of Competitive Intensity on Equilibrium Solution. Herein, the influence of competitive intensity between two automobile manufacturers on the equilibrium solution of the supply chain is evaluated. The results are illustrated in Figures 13–17.

Figure 13 shows that, with the increase of competitive intensity, CJ > OJ > OL, and CL first increases and then

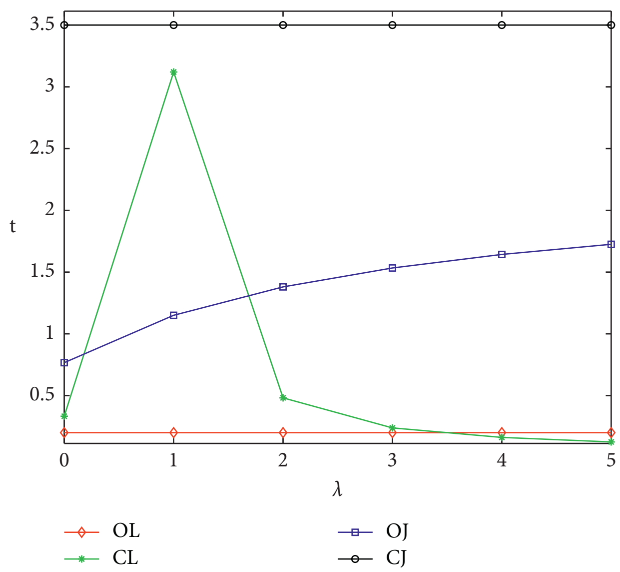

Figure 13: The influence of competitive intensity on new product technology content.

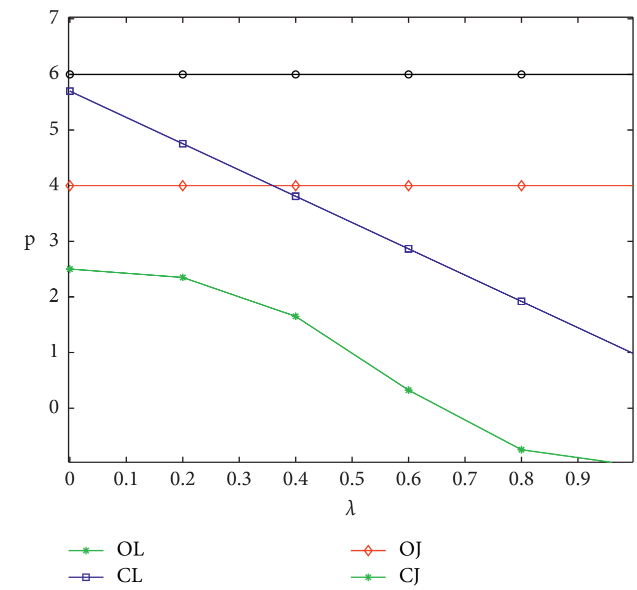

Figure 15: The influence of competitive intensity on market price.

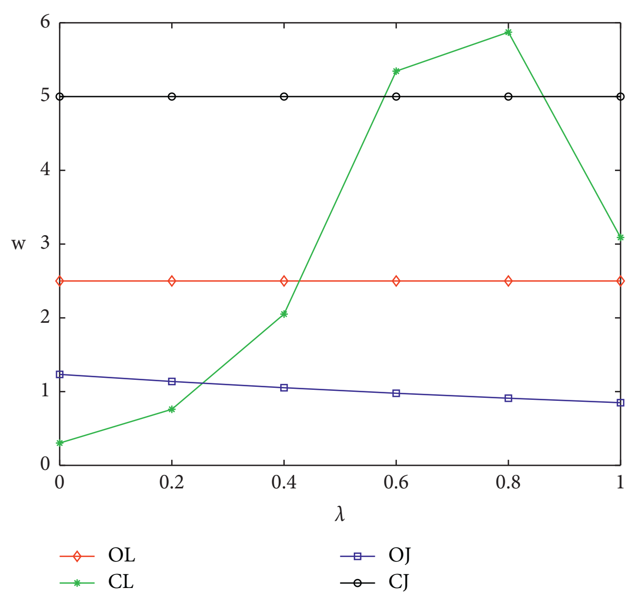

Figure 14: The influence of competitive intensity on wholesale price.

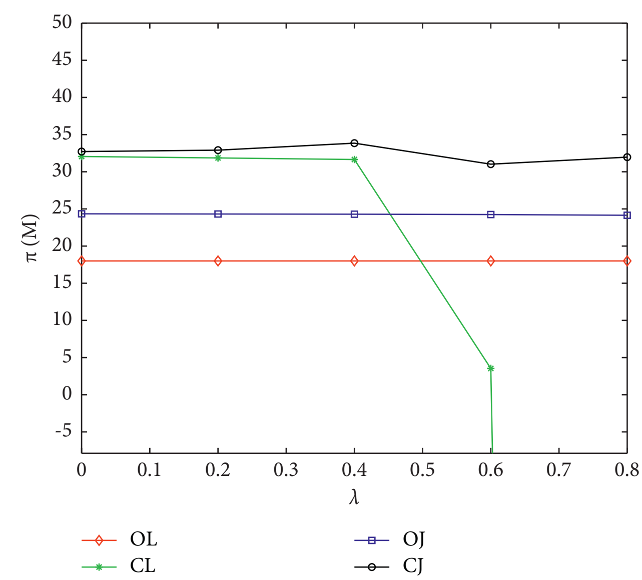

Figure 16: The influence of competitive intensity on total profit of automobile manufacturers.

decreases. To improve the technical content of new products, the competitive intensity must be controlled within a reasonable range. Meanwhile, the technical content of new product in OL and CJ will not change with the increase in the intensity of competition but will increase in OJ.

Figure 14 illustrates that the competitive intensity does not affect the wholesale price of OL and CJ, and CJ > OL > OJ, indicating that cooperative R&D is better than independent R&D. In addition, when $0 < \lambda < 0.8$, the technical content of new products of CL increases with the competitive intensity.

Figure 15 shows that the competitive intensity does not affect the market price of CJ and OJ, while the market price of CL and OL decreases with increasing competitive intensity. When the competition is not fierce, $0 < \lambda < 0.36$, cooperative R&D is superior to independent R&D; when $\lambda > 0.36$ and the competition is increasingly fierce, independent R&D is superior to cooperative R&D.

Figure 16 demonstrates that the competitive intensity does not affect the total profit of manufacturers under OJ and OL strategies. Whether the competition is fierce or not, the automobile dealer can obtain the highest profit under the CJ strategy. When $\lambda \geq 0.6$, the total profit of automobile manufacturers under a CL strategy decreases to zero, indicating that, when the competition is fierce, the CL strategy will reduce the profit earned by the automobile dealer.

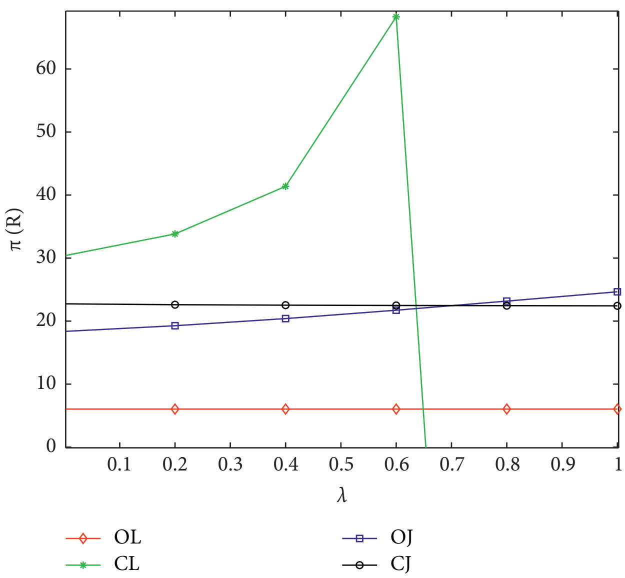

Figure 17: The influence of competitive intensity on the profit accruing to an automobile dealer.

Figure 17 depicts that as the competitive intensity increases, the profit of automobile dealer remains unchanged under the OL strategy, and increases under the OJ and CJ strategies, and first increases and then decreases under the CL strategy. In the case of $\lambda < 0.6$, the automobile dealer can obtain the maximum profit under the CL strategy, and CL > CJ > OJ > OL, indicating that cooperative R&D is better than independent R&D. When the competition is very fierce ($\lambda > 0.6$), OJ > CJ > OL, OJ is superior to OL.

6. Conclusion

The horizontal competition-cooperation game strategy of technological innovation in two-stage automobile cluster supply chain composed of duopoly of automobile manufacturers and a single automobile dealer is explored. According to the competition-cooperation relationship and R&D mode of horizontal automobile manufacturers, four game models of technological innovation are constructed and used to analyse the equilibrium solution under different game situations. The main conclusions and recommendations are as follows:

(1) The game equilibrium strategy of fully cooperative innovation can maximise the technical content of new product, wholesale price, and total profit of automobile manufacturers but cannot maximise the profit to the automobile dealer. This is mainly because fully cooperative innovation can reduce repetitive R&D costs resulting in the highest wholesale price, thus bringing more profits to automobile manufacturers; however, for the automobile dealer, OJ is the optimal strategy. Therefore, to maximise the total profit of automobile manufacturers and dealer, cooperative R&D mode should be selected to improve the degree of information sharing and share the R&D costs.

(2) When the horizontal competition is not fierce and the consumption preference for technical content is weak, the OJ strategy will bring the maximum profit to the automobile dealer, but will reduce the profit of automobile manufacturers, and the profit of the manufacturer is the lowest among the four game strategies under OJ strategy; with the intensification of horizontal competition, automobile manufacturers will inevitably lower the wholesale price to seize the market, increasing the profit of the automobile dealer under the game equilibrium strategy of OL to a level above that accruing under the OJ strategy. In addition, it also suggests that automobile manufacturers should adopt a differentiation strategy to maintain certain differences of products when developing new products in horizontal cooperation, thus reducing the competitive intensity between the two products and obtain more profits.

(3) No matter how the competition and cooperation relationship and the R&D model change, the market demand, wholesale price, market sales price, and technical content of new products will increase with the increase of consumer preference for the new products' technical content, but the growth rate under each game equilibrium strategy is different, and is greatest under the OJ strategy. Therefore, channel members along the automotive supply chain will enhance the technical content of new products by increasing investment in new product R&D and accelerating technical innovation. In addition, market preference for technical content of automotive products can bring more potential benefits to supply chain channels. Supply chain decision-makers should grasp the market opportunities brought by technical content preference to promote the benign development of the automotive supply chain.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

Research on the Artistic Conception of Multimedia-Assisted Ancient Poetry Based on AI Technology

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In order to improve the visual display effect of the artistic conception of ancient poems, this paper combines AI technology to construct a multimedia-assisted artistic conception creation system of ancient poetry and combines probabilistic latent semantic analysis to analyze the semantic artistic conception of ancient poetry. Moreover, with the support of multimedia simulation technology, this paper improves the multimedia teaching mode to improve the effect of multimedia-assisted ancient poetry teaching. In addition, this paper constructs a multimedia-assisted artistic conception creation system of ancient poetry based on AI technology and designs experiments to conduct system performance research. The experimental research results show that the multimedia-assisted artistic conception creation system of ancient poetry proposed in this paper has a good teaching effect and has an important role in promoting the study of the artistic conception of ancient poetry.

1. Introduction

It is difficult to understand the author's thoughts and feelings and experience the beauty of the artistic conception of poetry. When teaching ancient poems to students, the teacher needs to combine the cognitive characteristics of different ages to make students fully understand the writing mentality and historical background of the poet during the creation period, so as to induce students' interest in learning ancient poems. Therefore, before each study of an ancient poem, we will arrange a certain amount of spare time for students to go online and use network technology to find, view, and collect relevant information to understand the author's profile, historical background, and corresponding introduction of the poem, so that students have a rough understanding of the poems they have learned and lay a certain teaching foundation.

In the current Chinese teaching in my country, whether it is before or after the release of the new curriculum standard reform, ancient poetry plays a very important role in Chinese teaching at the university level. The reason is that, compared with modern poems and essays, ancient poems have extraordinary significance. Ancient poetry contains a wealth of traditional culture, and through the study of ancient poetry, college students can effectively improve their language expression ability and understand the many situations of ancient society. The improvement that this brings to the students is an improvement in comprehensive literacy, not a unilateral improvement. Especially in recent years, college Chinese textbooks have continued to change, and the proportion of ancient poems in them is increasing, which also proves the importance of ancient poems in the current college Chinese teaching. Multimedia technology is an innovative teaching model that emerged after informatization has penetrated into teaching, which is very popular among students. In addition, it can effectively improve the quality of teaching and can also fully stimulate students' interest in learning. In the current college Chinese ancient poetry teaching, the use of multimedia technology will inevitably improve the teaching effect.

Although the ancient poems at the university stage are relatively simple ancient poems, and some can even be understood in the vernacular way, in the process of teaching, because the college students are younger, they are understanding a lot. In the process of the content, due to insufficient cognitive level and insufficient life experience, there will be more serious problems in understanding. For many ancient poems, college students cannot understand the meaning of ancient poems, not to mention the rich thoughts and feelings contained in them. Therefore, in the process of teaching ancient poetry, teachers need to use their own teaching strategies to help students enter a specific teaching situation and guide students to understand the meaning of poetry. To understand the text in ancient poems, multimedia will help us a lot in this process. Using multimedia to create teaching situations can not only effectively improve efficiency but also better integrate students into the teaching situation.

Most of the life experiences of ancient poets have many ups and downs, and the works created by these poets in different periods completely express different thoughts and feelings. Therefore, teachers can use this in the process of teaching. The feature allows students to understand the author's life experience first, and then to understand the author's work, so that students will experience the author's mood at the time and have a better understanding of the thoughts and feelings to be expressed in the article. Poets are great. Most, in the process of writing poems, describe their own circumstances or ideals at the time. Therefore, it is more important to understand the circumstances of the author at that time. So the most effective way to help students understand the author is nothing more than multimedia. Teachers can use the Internet to search for the author's life events in detail, highlighting the key points and the events experienced by the author in the process of writing this poem, so that students can understand the poet at that time more clearly.

This paper combines AI technology to improve the multimedia teaching mode and improve the effect of multimedia-assisted ancient poetry teaching, which lays the foundation for the subsequent improvement of the quality of ancient poetry teaching.

2. Related Work

A physics-based simulation method simulates the painting process by building models of painting tools such as pens and paper, using image analogy, texture synthesis, and other methods to achieve the artistic effect of virtual reality. Literature [1] proposed a method of simulating hand-painting with style strokes, and literature [2] proposed a virtual brush model (HairyBrush), which can simulate simple ink painting effects. Reference [3] proposes a virtual art pen model based on the elasticity theory, which satisfies the elastic deformation law and models the art pen as an inverted cone to achieve real-time display effects; reference [4] proposes a virtual art pen model. brush model, which can generate more realistic writing effects. Literature [5] proposed a physics-based Mao Fei physical simulation method mainly to simulate the rendering effect. The model proposed in [6] can simulate the effect of ink diffusion on paper. The system developed in [7] can be used to draw trees, and the effect generated by the system is similar to the effect of oil painting. The method proposed in [8] simulates the effect of artistic painting and develops a corresponding system.

In terms of simulation based on painting effects, literature [9] uses the method of image analogy to achieve artistic style drawing. Literature [10] proposes a method of texture synthesis, proposes common textures from artistic paintings, establishes a texture library, and then selects appropriate textures from the texture library to synthesize new ink paintings. Literature [11] designed a paint model that can express a variety of painting forms including traditional Chinese paintings and watercolors. Many scholars are dedicated to studying how to use computers to generate artistic painting effects. Literature [12] proposes a method of synthesizing artistic paintings based on images and has conducted research on computer rendering of artistic paintings. Literature [13] proposed an art painting system simulation rendering algorithm based on texture synthesis. Literature [14] has done research on the rendering effect of art, which is an attempt to realize the style application of animation ink and wash effect. Literature [15] proposes a design method of dynamic artistic conception in order to protect cultural heritage. The 3D mountain rock model constructed in [16] successfully realized the 3D rendering of the art painting simulation effect of the pen and ink method. This method is based on summarizing the shape and distribution of the pen and ink method in the art painting and proposes a fractal modeling method based on the sketch line. Literature [17] designed a form that can automatically generate ancient cultural connotations from pictures in real time. Literature [18] proposes a tool based on the movement trajectory of the artistic pen and the painting material, which can vividly show the process of artistic painting. In recent years, the innovation of computer technology has led to the rapid development of programmable graphics hardware. Programmable graphics software has become an important tool for scholars to conduct research on 3D graphics rendering. Literature [19] proposed the use of programmable graphics hardware to achieve the effect of hand-drawn Chinese painting. In terms of interactive experience, [20] pointed out that, in order to protect art treasures but still allow people to appreciate them, an interactive desktop that can watch artworks at close range is developed. Viewers can achieve partial magnification of the screen through touch points on the desktop. Literature [21] proposed a new method of displaying and restoring ancient famous paintings from a three-dimensional perspective using TIP technology. Now this system can only display animation effects and cannot achieve interaction.

3. Multimedia Virtual Semantic Extraction of Ancient Poetry

Probabilistic latent semantic analysis (PLSA) is a statistically significant model proposed by Hofmann, which is mainly used in text classification and natural language research. When researching natural language, it is often necessary to research synonyms. Probabilistic latent semantics is a better way to solve this kind of research problems. By mapping the high-dimensional sparse vector space of the actual observable "document-word" to the low-dimensional latent space, a connection beyond the vocabulary level is established.

In the PLSA model, we set the document set $D = \{d_1, d_2, \ldots, d_N\}$ and the word set $W = \{w_1, w_2, \ldots, w_M\}$, and the $N \times M$ cooccurrence matrix N composed of the document set D and the word set W, as shown in

$$N = \begin{bmatrix} n(d_1, w_1) & n(d_1, w_2) & \cdots & n(d_1, w_M) \\ n(d_2, w_1) & n(d_2, w_2) & \cdots & n(d_2, w_M) \\ \vdots & \vdots & \ddots & \vdots \\ n(d_N, w_1) & n(d_N, w_2) & \cdots & n(d_N, w_M) \end{bmatrix}. \quad (1)$$

Here, d_i represents the i-th document, w_j represents the j-th word, and $n(d_i, w_j)$ represents the number of times the j-th word appears in the i-th document. In matrix N, each row represents the number of times each word appears in a certain document, and each column represents the number of times a certain word appears in each document. We assume that there is an implicit variable z, that is, the subject variable. If $P(d_i)$ is used to indicate the probability of selecting the i-th document, $P(z_k \mid d_i)$ is the probability of the topic z_k appearing in the i-th document. $P(w_j \mid z_k)$ represents the probability that the word w_j appears in the k-th topic, and the relationship between the three is shown in Figure 1.

If it is assumed that document d and word w are conditionally independent under topic z, formula (2) can be used to express the cooccurrence probability of document d and word w.

$$P(d_i, w_j) = P(d_i)P(w_j \mid d_i) = P(d_i) \sum_{k=1}^{K} P(w_j \mid z_k) P(z_k \mid d_i). \quad (2)$$

It can be seen from formula (2) that PLSA is actually a mixed model, and there are two model parameters $P(z \mid d)$ and $P(w \mid z)$. Here, $P(z \mid d)$ is the probability distribution of topic z under a given document d, and $P(w \mid z)$ is the probability distribution of word w under a given topic z. In the PLSA model, the parameters $P(z \mid d)$ and $P(w \mid z)$ are estimated by using the maximum likelihood estimation method to maximize the probability of the generated sample data. The maximum likelihood function is shown in

$$\begin{aligned} L &= \sum_{i=1}^{N} \sum_{j=1}^{M} \log P(d_i, w_j)^{n(d_i, w_j)} \\ &= \sum_{i=1}^{N} \sum_{j=1}^{M} n(d_i, w_j) \log P(d_i, w_j) \\ &= \sum_{i=1}^{N} n(d_i) \left[\log P(d_i) + \sum_{j=1}^{M} \frac{n(d_i, w_j)}{n(d_i)} \log \sum_{k=1}^{K} P(w_j \mid z_k) P(z_k \mid d_i) \right]. \end{aligned} \quad (3)$$

Here, $n(d_i) = \sum_{j=1}^{M} n(d_i, w_j)$, and $n(d_i)$ is not model parameters, so the formula can be reduced to

$$L \propto \sum_{i=1}^{N} \sum_{j=1}^{M} n(d_i, w_j) \log \sum_{k=1}^{K} P(w_j \mid z_k) P(z_k \mid d_i). \quad (4)$$

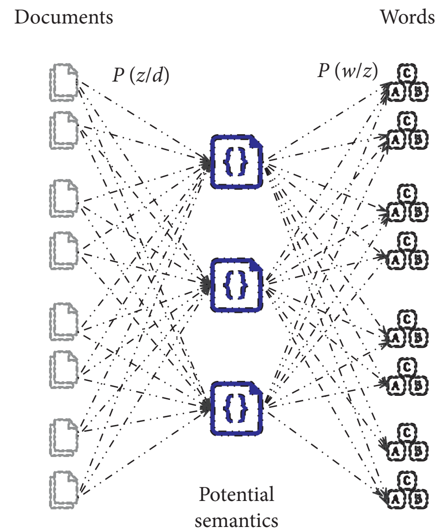

Figure 1: The relationship diagram of "document-latent semantics-word."

It can be seen from formula (4) that $P(z \mid d)$ and $P(w \mid z)$ are the parameters required by the maximum likelihood estimation function. However, since the likelihood function is difficult to maximize, the EM algorithm must be introduced.

The algorithm is an iterative algorithm, divided into two steps. The first step is a step, and what you ask for is expectations. The second step is step, which is the maximum value. The details are shown in formulas (5), (6), and (7).

(1) Step E: the algorithm generates a posterior probability $P(z_k \mid d_i, w_j)$ for each (d_i, w_j):

$$P(z_k \mid d_i, w_j) = \frac{P(w_j \mid z_k) P(z_k \mid d_i)}{\sum_{k=1}^{K} P(w_j \mid z_k) P(z_k \mid d_i)}. \quad (5)$$

(2) Step M: the algorithm reestimates the model parameters $P(z \mid d)$ and $P(w \mid z)$:

$$P(w_j \mid z_k) = \frac{\sum_{i=1}^{N} n(d_i, w_j) P(z_k \mid d_i, w_j)}{\sum_{j=1}^{M} \sum_{i=1}^{N} n(d_i, w_j) P(z_k \mid d_i, w_j)}, \quad (6)$$

$$P(z_k \mid d_i) = \frac{\sum_{j=1}^{M} n(d_i, w_j) P(z_k \mid d_i, w_j)}{\sum_{i=1}^{N} \sum_{j=1}^{M} n(d_i, w_j)}. \quad (7)$$

(3) Iteration termination condition is as follows:

After initializing $P(z \mid d)$ and $P(w \mid z)$, the EM algorithm alternately performs E and M steps for iterative calculation and generates new $P(z \mid d)$ and $P(w \mid z)$ until $E(L)$ reaches convergence:

$$E(L) = \sum_{i=1}^{N} \sum_{j=1}^{M} n(d_i, w_j) \sum_{k=1}^{K} P(z_k \mid d_i, w_j) \log \left[P(w_j \mid z_k) P(z_k \mid d_i) \right]. \quad (8)$$

PLSA is mainly divided into two processes of training and testing in image quality evaluation. Among them, in the training process, the visual words and the visual word distribution under each latent semantics are obtained by extracting features and clustering from the training image set. In the testing process, the latent semantic distribution of the test image set is compared with the latent semantic distribution of the reference image, and then the quality score of the image is obtained. The specific process is shown in Figure 2.

It can be seen from Figure 2 that the image quality score is obtained by calculating the semantic similarity of the latent semantic distribution $P(z \mid d_{train})$ of the training image set and the latent semantic distribution $P(z \mid d_{test})$ of the test image set. The specific process is to separately propose the latent semantic distribution of the undistorted image and calculate the average value of the latent semantic distribution according to formula (9) as a reference value for comparison. The specific process is to separately propose the latent semantic distribution of the undistorted image and calculate the average value of the latent semantic distribution according to formula (9) as a reference value for comparison. Here, N_p is the number of reference images.

$$P_G = \frac{1}{N_P} \sum_{i=1}^{N_P} P(z \mid d_i). \tag{9}$$

There should be a certain nonlinear relationship between the subjective data and the objective data of image quality evaluation. Generally, the nonlinear function selected should be monotonous, and it is best to avoid data overfitting. Therefore, this paper uses the commonly used logarithmic regression function for fitting, and the function expression is

$$SS_p = f(OS) = \frac{b_1}{1 + \exp(b_2 * (OS - b_3))} + b_4 * OS + b_5. \tag{10}$$

Here, f represents the nonlinear relationship, SS_p is the fitted value, that is, the predicted subjective quality value, which is a deformation of OS, and OS is the objective evaluation value. b_1, b_2, b_3, b_4, b_5 can be obtained by fitting. Figure 3 shows the prediction accuracy of the subjective MOS value, where the curve is the fitting curve of the nonlinear regression function, and the scattered points near the curve represent the data pair (OS, SS_P).

In Figure 3, the smaller the error between SS_P and MOS, the higher the accuracy of the algorithm. Currently, the commonly used method is taken from the performance evaluation algorithm proposed by the Video Quality Evaluation Group (VQEG). That is, the five indicators of Pearson correlation coefficient (CC), root mean square error (RMSE), average absolute error (RMSE), Spearman rank correlation coefficient (ROCC), and rate of dispersion (OR) are used as methods to evaluate the accuracy of the algorithm:

The Pearson correlation coefficient (CC) is

$$CC = \frac{\sum_{i=1}^{n} (X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n} (X_i - \overline{X})^2 \sum_{i=1}^{n} (Y_i - \overline{Y})^2}}. \tag{11}$$

Here, X_i and Y_i are subjective and objective evaluation scores, respectively, and $\overline{X}$ and $\overline{Y}$ are, respectively, the mean value of subjective and objective evaluation.

(2) The root mean square error (RMSE) is

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (X_i - Y_i)^2}. \tag{12}$$

Here, X_i is the subjective evaluation score, and Y_i is the SS_P value.

(3) The average absolute error (MAE) is

$$MAE = \frac{1}{n} \sum_{i=1}^{n} |X_i - Y_i|. \tag{13}$$

Here, X_i is the subjective evaluation score, and Y_i is the SS_p value.

(4) The Spearman rank correlation coefficient (ROCC) is

$$ROCC = 1 - \frac{6 \sum_{i=1}^{n} (RX_i - RY_i)^2}{n(n^2 - 1)}. \tag{14}$$

Here, RX_i and RY_i, respectively, represent the data after the subjective and objective scores are sorted in the same order.

(5) The dispersion rate is

$$OR = \frac{n_{owt}}{n}. \tag{15}$$

Here, n_{out} is the number of points where the deviation between the fitted value and the subjective value is greater than 1.5.

In formula (11), the Pearson correlation coefficient can measure whether two data sets are on a straight line. The greater the absolute value of the correlation coefficient, the stronger the correlation. The root mean square error in formula (12) can measure the deviation between the predicted value and the subjective value. The smaller the deviation, the better the algorithm performance. The Spearman rank correlation coefficient in formula (14) can measure the monotonicity of two data sets. The larger the absolute value of ROCC, the stronger the monotonicity. The smaller the OR in formula (15), the higher the degree of aggregation of the algorithm. Therefore, the larger the value of CC and ROCC, the better the performance of the image quality evaluation algorithm. The smaller the MAE, RMSE, and OR, the worse the image quality evaluation algorithm.

Image semantics is the basic description carrier of image information content. It can convert the complete image content into an intuitively understandable text-like language expression. It is the high-level content in the field of image research and plays a vital role in the objective quality evaluation of images.

In the PLSA-based image quality evaluation, the specific application of image semantics reflects two aspects. One

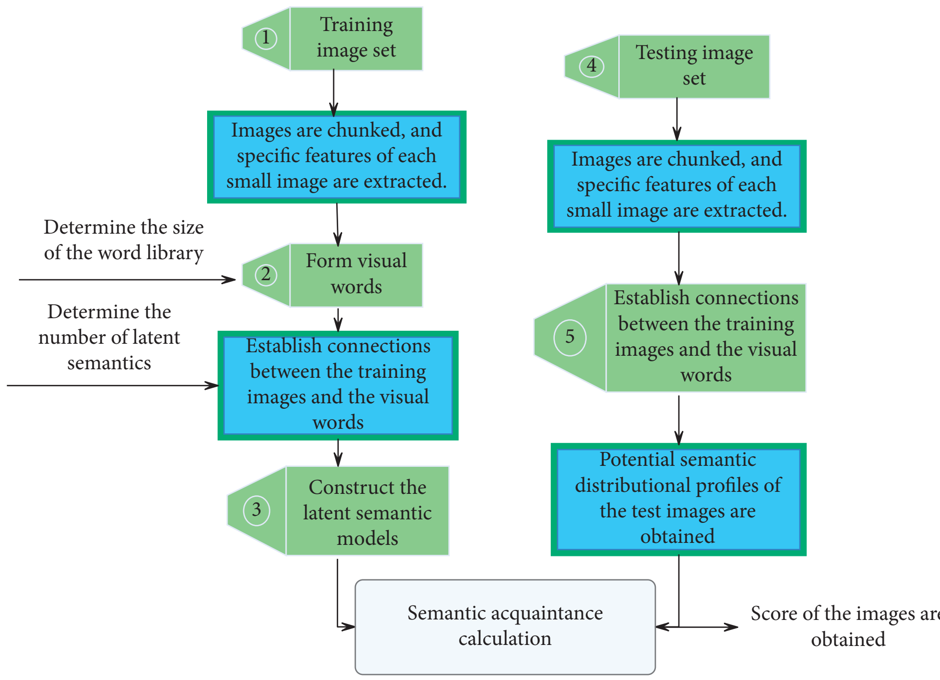

Figure 2: Flowchart of image quality evaluation.

aspect is the construction of the model. That is, after the low-level feature extraction is performed on the undistorted images and training images, the semantics are implicitly incorporated into them. This maps the high-dimensional "image-visual word" cooccurrence matrix to the low-dimensional space, thereby establishing a probability model between "image-latent semantics-visual word." On the other hand, it is reflected in the analysis of semantics, that is, the measurement of semantic similarity. Based on the rule that the latent semantic distribution of distorted images of the same type and level has similar laws, the latent semantic distribution of distorted images of different types or different levels often has certain differences. The semantic similarity measure takes the latent semantic distribution $P_{pristine}(z \mid d)$ of the undistorted image as the criterion for evaluation and comparison and then compares it with the latent semantic distribution $P_{\text{test}}(z \mid d)$ of the test image to obtain the objective score of the image. Therefore, choosing a reasonable semantic similarity measurement method is the final key step to obtain a better image quality evaluation algorithm.

For a given distorted image, this paper first calculates the normalized brightness through local mean subtraction and standardized splitting.

Ruderman believes that a local nonlinear operator can be added to the logarithmic ratio brightness to remove the local mean deviation and the standardized local variance, and there is no correlation between the two. This operator can be obtained from a given image:

$$\widehat{I}(i,j) = \frac{I(i,j) - \mu(i,j)}{\sigma(i,j) + C}. \tag{16}$$

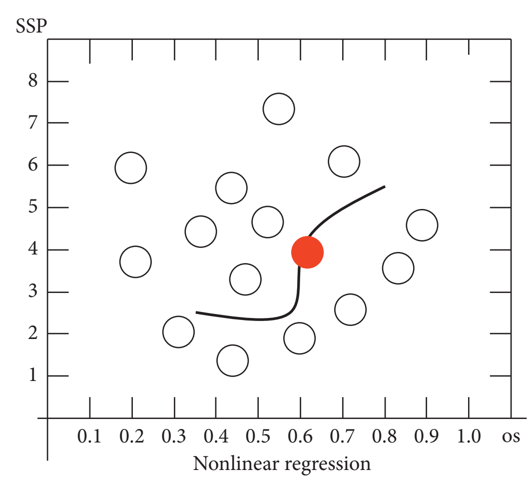

Figure 3: Accuracy map of subjective MOS prediction.

Here, $i \in 1, 2 \ldots M$, $j \in 1, 2 \ldots N$.M, N is the height and width of the image. $C = 1$ is a constant, because when the denominator approaches 0, $C = 1$ can prevent system instability.

$$\begin{aligned} \mu(i,j) &= \sum_{k=-K}^{K} \sum_{l=-L}^{L} \omega_{k,l} I_{k,l}(i,j), \\ \sigma(i,j) &= \sqrt{\sum_{k=-K}^{K} \sum_{l=-L}^{L} \omega_{k,l} \left(I_{k,l}(i,j) - \mu(i,j)\right)^2}. \end{aligned} \tag{17}$$

Here, $\omega = \{\omega_{k,l} \mid k = -K, \ldots, K, l = -L, \ldots, L\}$, and ω is a set of two-dimensional circularly symmetric Gaussian weight functions.

Ruderman also observed that the normalized brightness value of natural images tends to unit Gaussian features, and this feature can be used in the contrast gain mask processing model in early human vision. In the image quality evaluation system, the brightness value $\widehat{I}(i, j)$ can be converted into MSCN (mean subtracted contrast normalized) coefficients. In the picture shown on the left picture of Figure 4, it can be seen that there is a relatively high correlation between adjacent pixels, and a diagonal structure is observed in the left picture. As shown on the right side of Figure 4, the normalization method reduces the correlation between adjacent pixels of the image.

Of course, this problem can be solved by modulating the matrix of the topic distribution probability under each image, but this also causes the score of the test image to exceed the score of the reference image. Therefore, it is unreasonable. This also shows that, to some extent, KL distance is actually not suitable as a semantic similarity algorithm for image quality evaluation. However, Hellinger distance does not have this problem. Hellinger distance is to calculate the square of the difference between P_G and $P(z \mid I)$, so we only need to subtract the two matrices and then square each element, and we do not need to consider other factors. Therefore, Hellinger distance is more suitable for image quality evaluation than KL distance, and it can be used as a semantic similarity algorithm together with cosine similarity in image quality evaluation.

The MSCN coefficient has the characteristic of changing with the distortion, and this feature can ensure that the distortion type that affects the image quality is predicted through the image distortion change. The distribution of MSCN coefficients of blur features (blur) is closer to the Laplacian feature, while the distribution of MSCN coefficients of white noise (wn) reduces the weight of the tail of the histogram. The generalized Gaussian distribution (GGD) can effectively capture the statistical characteristics of the distorted image, and its zero-mean expression is as follows:

$$\begin{aligned} f\left(x; \alpha, \sigma^2\right) &= \frac{\alpha}{2\beta\Gamma(1/\alpha)} \exp\left(-\left(\frac{|x|}{\beta}\right)^{\alpha}\right), \\ \beta &= \sigma\sqrt{\frac{\Gamma(1/\alpha)}{\Gamma(3/\alpha)}}, \\ \Gamma(a) &= \int_0^{\infty} t^{a-1} e^{-t} dt \quad a > 0. \end{aligned} \tag{18}$$

Here, $\Gamma(.)$ is the gamma function. Since the coefficient distribution is symmetric, it can be described by the zero-mean GGD distribution. Among them, the parameter (α, σ^2) of the GGD distribution can be fitted by the time-moment matching method.

In fact, in the GGD distribution model of the reference image and the distorted image, the parameter settings are almost the same. For each image, the MSCN coefficient can be fitted by estimating the two parameters (α, σ^2) in the GGD distribution model. These two parameters form the first two dimensions of the multidimensional feature and are used to capture the distortion type of the image. As for the other several-dimensional features of multidimensional features, the asymmetric generalized Gaussian distribution model can be used, and its formula is as follows:

$$f\left(x; \nu; \sigma_l^2; \sigma_r^2\right) = \begin{cases} \dfrac{\nu}{(\beta_l + \beta_r)\Gamma(1/\nu)} \exp\left(-\left(\dfrac{-x}{\beta_l}\right)^{\nu}\right), \\ \\ \dfrac{\nu}{(\beta_l + \beta_r)\Gamma(1/\nu)} \exp\left(-\left(\dfrac{-x}{\beta_r}\right)^{\nu}\right), \\ \\ x \geq 0. \end{cases} \tag{19}$$

Here,

$$\begin{aligned} \beta_l &= \sigma_l\sqrt{\frac{\Gamma(1/\nu)}{\Gamma(3/\nu)}}, \\ \beta_r &= \sigma_r\sqrt{\frac{\Gamma(1/\nu)}{\Gamma(3/\nu)}}. \end{aligned} \tag{20}$$

ν is the shape parameter of the image, which determines the distortion type of the image, and ${\sigma_l}^2$ and ${\sigma_r}^2$ are the scale parameters that control the distribution of each side of the model. In fact, the AGGD model is a generalization of the GGD model. The reason is that the AGGD model is mainly for the asymmetric MSCN coefficient distribution, and the slope of the distribution is an equation about the left and right scale parameters. When $\sigma_l^2 = \sigma_r^2$, the AGGD model is transformed into the GGD model. When $\eta = (\beta_r - \beta_l)(\Gamma(2/\nu))/(\Gamma(1/\nu))$, the parameters $(\eta, \nu, \sigma_l^2, \sigma_r^2)$ of the best AGGD model can be fitted.

Due to the existence of image distortion, adjacent MSCN coefficients will show a certain "structure." Therefore, this "structure" can be obtained by calculating the statistical relationship between adjacent pixels in the four directions of the horizontal direction (H), vertical direction (V), main diagonal (D1), and subdiagonal (D2), as shown in Figure 4 and formula (21).

$$\begin{aligned} H(i, j) &= \widehat{I}(i, j)\widehat{I}(i, j + 1), \\ V(i, j) &= \widehat{I}(i, j)\widehat{I}(i + 1, j), \\ D1(i, j) &= \widehat{I}(i, j)\widehat{I}(i + 1, j + 1), \\ D2(i, j) &= \widehat{I}(i, j)\widehat{I}(i + 1, j - 1). \end{aligned} \tag{21}$$

In this way, the abovementioned four directions are considered at the same time, and each direction is described by four parameters; that is, a total of 16 parameters constitute the 16-dimensional feature of the image.

Since human vision is multiscale, when people are observing images, the acquisition of image feature information will be interfered by scales. According to recent research on image quality evaluation, the quality evaluation algorithm combined with multiscale information can better express the correlation with human perception. Therefore, two scales of the original image and the reduced one-time image can be used to extract a total of 36-dimensional features of the image.

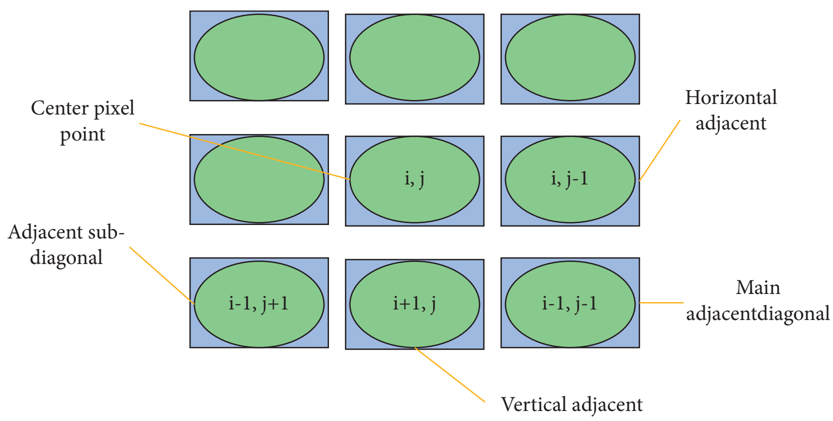

Figure 4: Image structure model diagram.

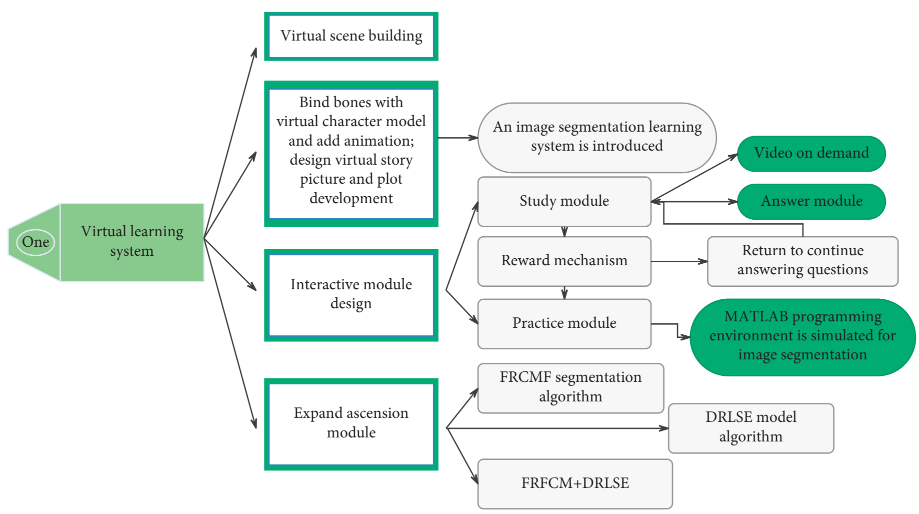

Figure 5: System technical block diagram.

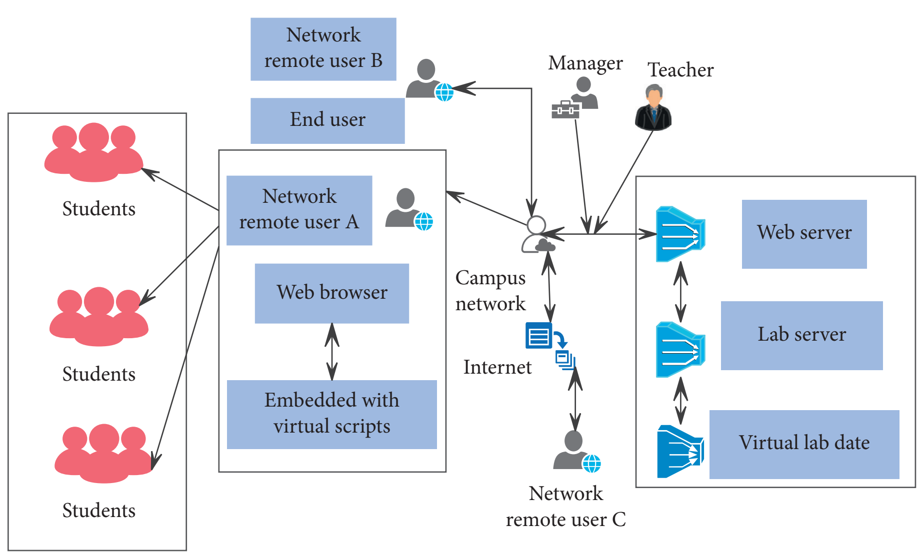

Figure 6: System overall design framework.

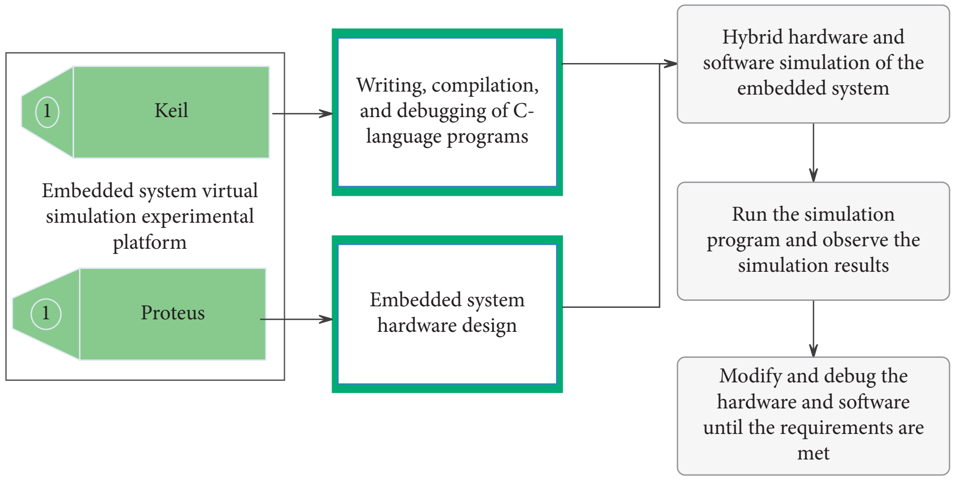

Figure 7: Virtual simulation experiment process of embedded system.

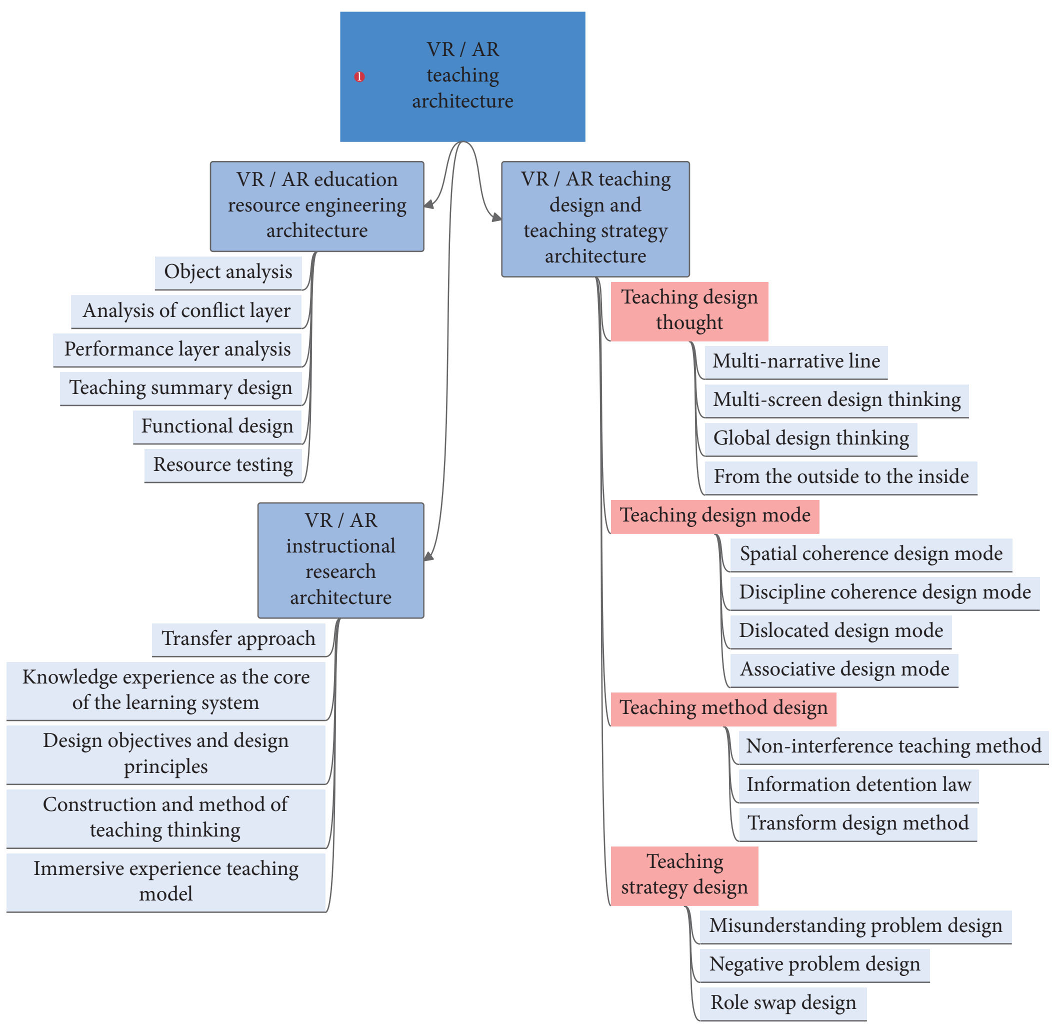

Figure 8: VR/AR teaching system architecture diagram.

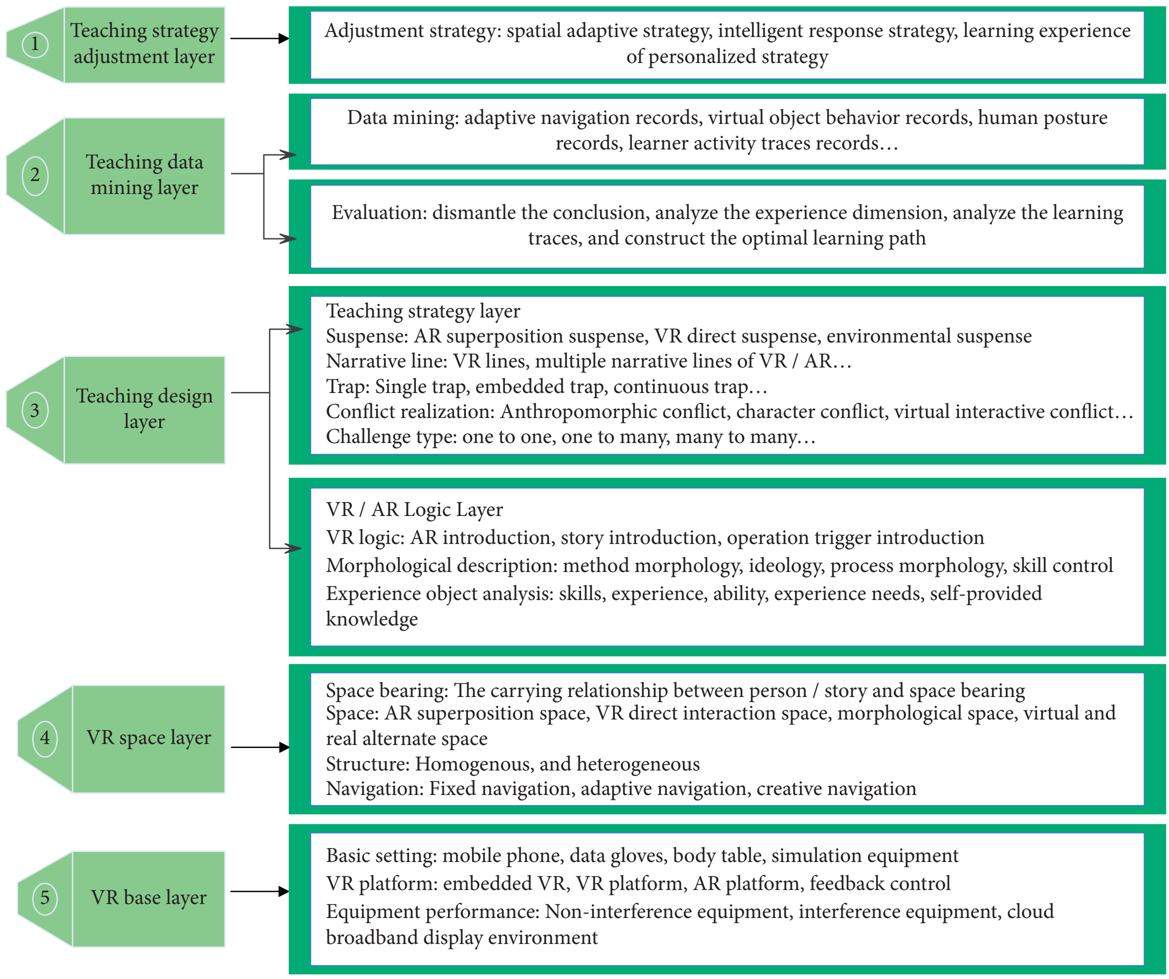

Figure 9: VR/AR intelligent virtual teaching control physical model.

4. The Multimedia-Assisted Ancient Poetry Teaching System Based on AI Technology

The learning system creates virtual characters in the first person by default, and learners roam and learn in the virtual scene according to the prompts. The overall technical block diagram of the system is shown in Figure 5.

Through the intelligent teaching system, it is helpful to mobilize students' enthusiasm and initiative in the classroom, to improve their learning efficiency, and to cultivate students' practical ability and innovation ability. The overall design framework of the system is shown in Figure 6.

This paper uses Proteus and Keil software to build an embedded system virtual simulation platform. The simulation process of 5l one-chip computer embedded system is shown as in Figure 7. First, this paper uses Proteus to draw a schematic diagram, selects Keil software to design the source code, then compiles the code, generates the target file, and then loads the HEX file in the Proteus software.

This research designs its system architecture for VR/AR teaching needs. It mainly describes the abstract components that directly constitute the VR/AR teaching system, including VR/AR teaching research architecture, VR/AR teaching design and teaching strategy framework, and VR/AR education resource engineering framework. The specific research content is shown in Figure 8.

The AR/AR space layer contains various learning spaces of the system, including VR direct interaction space, AR superimposed space, morphological space, and virtual-real interlaced space. These spaces can be divided into four types according to their structure and properties: isomorphism and homogeneity, heterogeneity and homogeneity, isomorphism and heterogeneity, and heterogeneity and heterogeneity. In addition, the VR space also reflects the bearing relationship between people/story and space. There are four relationships between them: 1 : 1, 1 : N, N : 1, and N : N. It is one person and one space, one person and multiple spaces, multiple people and one space, multiple people and multiple spaces, one story and one space, one story and multiple spaces, multiple stories and one space, and multiple stories and multiple spaces. In the space, learners complete their own learning process through fixed navigation, adaptive navigation, and creative navigation, as shown in Figure 9.

This paper takes "Wanglu Mountain Waterfall" as an example to conduct multimedia-assisted research on ancient poetry teaching, and its image processing is shown in Figure 10.

Through the analysis of Figure 10, it can be seen that the multimedia-assisted artistic conception creation system of ancient poetry based on AI technology can basically meet the

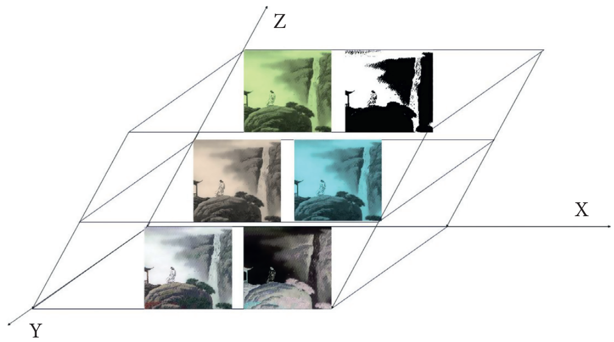

Figure 10: An example of the creation of multimedia-assisted artistic conception of ancient poetry based on AI technology.

Table 1: Immersive evaluation of the multimedia-assisted artistic conception creation system of ancient poetry based on AI technology.

No.	Immersion	No.	Immersion	No.	Immersion
1	88.74	16	86.15	31	86.73
2	81.99	17	90.70	32	82.53
3	80.40	18	91.02	33	84.18
4	91.60	19	81.61	34	91.15
5	85.83	20	80.70	35	83.81
6	91.07	21	90.38	36	84.85
7	79.61	22	79.66	37	85.04
8	82.54	23	90.31	38	87.21
9	80.33	24	87.93	39	80.77
10	86.91	25	88.86	40	84.74
11	90.06	26	90.82	41	79.63
12	84.33	27	84.07	42	80.14
13	87.03	28	79.69	43	84.68
14	84.10	29	87.15	44	85.51
15	80.95	30	83.41	45	90.86

Table 2: Evaluation of the teaching effect of the multimedia-assisted artistic conception creation system of ancient poetry based on AI technology.

No.	Teaching effect	No.	Teaching effect	No.	Teaching effect
1	90.68	16	78.77	31	77.81
2	83.74	17	85.98	32	83.36
3	87.01	18	86.43	33	77.67
4	89.75	19	86.96	34	84.09
5	74.99	20	84.07	35	89.22
6	80.11	21	80.84	36	77.38
7	77.77	22	90.55	37	77.79
8	79.21	23	81.58	38	80.46
9	76.72	24	87.46	39	83.85
10	88.31	25	90.68	40	86.53
11	88.23	26	87.03	41	87.76
12	82.83	27	88.66	42	78.88
13	90.20	28	80.69	43	74.58
14	76.42	29	85.08	44	79.20
15	78.49	30	84.40	45	81.89

teaching needs. On this basis, this paper conducts research on the performance of the system and counts the immersion and teaching effect brought by the system to students. The results are shown in Tables 1 and 2.

From the above research, we can see that the multimedia-assisted artistic conception creation system of ancient poetry proposed in this paper has a good teaching effect and has an important role in promoting the study of the artistic conception of ancient poetry.

5. Conclusion

The linguistic features of ancient poems are very obvious; generally each sentence does not exceed seven characters. In a brief narrative, it either portrays a magnificent scene or a melancholy picture, which depends entirely on the author's thoughts and feelings at the time and the theme of the work itself. Therefore, ancient poems are an important form of writing in ancient China, and they are also of great significance in contemporary times. Many of the profound ideas still have reference significance today. This paper combines AI technology to improve the multimedia teaching mode, improve the effect of multimedia-assisted ancient poetry teaching, and lay the foundation for the subsequent improvement of the quality of ancient poetry teaching. The research shows that the multimedia-assisted artistic conception creation system of ancient poetry proposed in this paper has a good teaching effect and plays an important role in promoting the study of the artistic conception of ancient poetry.

Data Availability

The labeled datasets used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Transformation and Optimization of Rural Ecological Endowment Industry Chain Based on Constrained Clustering Algorithm

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China is experiencing a serious aging crisis, with the number of elderly people rising at an unprecedented rate. First and foremost, the pension industry's service object is the pension. To build an old-age industry complex, make use of the unique natural resources in the countryside, provide the original ecological old-age care services, and transform, optimize, and make efficient use of the existing policies and technologies. The drawbacks of the traditional pension model are becoming increasingly apparent. We must investigate a new pension model in order to ensure the long-term development of China's pension system and reduce the increased pension burden on governments at all levels. The rural areas' unique natural resources should be utilized to provide unique ecological elderly care services, and transformation and optimization must be implemented (that is, making efficient use of existing policies and technology to construct an elderly care industry complex). As a new pension mode for the elderly to become more connected to the natural world and improve their physical and mental health, ecological pensions have emerged as a new economic growth point that can fill the gap in the pension industry's supply while also meeting the elderly's growing spiritual and cultural needs. A constrained clustering algorithm is proposed in this article. Unsupervised learning is used in the constrained clustering algorithm. The clustering algorithm must determine the data objects to be clustered because they are not labeled. Because the data objects have no prior knowledge, the clustering algorithm analyzes them using the same principles. The effectiveness of the clustering results is determined by the dataset's adherence to the previously stated principles. The constrained clustering algorithm has greatly improved the transformation and optimization of the rural ecological elderly care industrial chain.

1. Introduction

With the deepening of China's aging population, the pension industry has gradually become a new sunrise industry, with an immeasurable development prospect [1]. China has been involved in a serious wave of aging, and the number of elderly people is increasing at an unprecedented rate. The existing old-age care institutions are far below the actual expectations of the people in terms of number and service quality [2]. The number of people over 60 years old will increase from 178 million to 221 million, with an average annual increase of 8.6 million. The proportion of the elderly population will increase from 13.3% to 16%, with an average annual increase of 0.54 percentage points. According to the forecast of the National Bureau of Population Statistics, by 2050, China's elderly population will reach 437 million, accounting for 30% of the total population, and the number will exceed the sum of the elderly population of developed countries in the world [3]. China is about to become a highly aging society, and the problem of providing for the aged has seriously restricted the development of China's economy. From the whole development process and coverage of the old-age care industry, it can be shown that the main characteristics of the old-age care industry are wide coverage, long industrial chain, sustainability, and environmental friendliness. First of all, the service object of the pension industry is pension. We made use of the unique natural resources in the countryside, provided the original ecological old-age care services, and transformed, optimized, and made efficient use of the existing policies and technologies to build an old-age industry complex [4]. The disadvantages of the traditional old-age care model are becoming more and more obvious. In order to make the long-term development of China's old-age care reduce the burdens of the old-age care on the governments at all levels, which are getting heavier and heavier, we must explore a new old-age care model [5]. Old-age care mainly includes family care, community care, and institutional care. Institutional care in real life includes pension yuan, nursing homes, and apartments for the elderly. These institutions are either public institutions or private institutions that provide old-age care services. As a new old-age care model, ecological old-age care, which enables the elderly to get close to the ecological environment and gain physical and mental health, has become a new economic growth point. Comparatively speaking, the investment risk of social capital is relatively high, and a complete mature model of investment in old-age care institutions has not yet been formed and most of the capital is still on the sidelines, which make it difficult for the government to really implement measures to encourage social forces to enter the old-age care industry [6, 7].

The clustering method is an unsupervised learning method. The data objects to be clustered are unmarked and need to be determined by the clustering algorithm itself. Because there is no background knowledge about data objects, the clustering algorithm uses the same principles to analyze these data, and whether the clustering results are effective depends on the degree to which the dataset conforms to the preestablished principles [8]. Clustering is the process of dividing objects into similar object classes according to some attributes of objects [8]. The goal of clustering is to make the objects in the class as similar as possible and the objects between classes as different as possible. Unlike classification [9–11], clustering usually has no prior knowledge or background knowledge as guidance. It is an automatic recognition [12] and unsupervised learning process based on object similarity [13].

The selection of cluster centers is based on the direction relationship instead of random selection, which makes the selection of cluster centers have good distribution and avoids the decrease of convergence speed caused by the concentration of cluster center distribution. Clustering with constraints refers to the method of expressing specific domain knowledge in the form of "constraints" and embedding it into the clustering process [14, 15]. Because of the use of domain knowledge, the clustering algorithm can obtain more heuristic information, thus reducing the "blindness" in its search process and improving the efficiency and clustering quality. Clustering with constraints refers to the method of expressing specific domain knowledge in the form of constraints and embedding it into the clustering process [16]. Because of the use of domain knowledge, the clustering algorithm can obtain more heuristic information, thus reducing the "blindness" in its search process and improving the efficiency and clustering quality. Supervised learning methods [17–19] require each data record to have a class label, while unsupervised learning methods do not consider any guiding information [20, 21]. Because users often have clear application requirements, in many practical applications, effective solutions tend to add user preferences or constraints to the clustering process, which has an important impact on the results of knowledge discovery and helps us find the knowledge patterns that users are interested in or more in line with users' needs. After the constrained clustering algorithm, through the analysis of the decision graph, a series of data points that may be the center of the cluster are selected in various ways, which is called the initial center point. The number of initial center points may be more than the real number of clusters, but the initial center points must be local high-density points in the data. By selecting the initial center point, the potential hierarchical structure information of the system can be extracted, which can serve as a heuristic for subsequent clustering [22].

2. Related Work

Literature [23] pointed out that the combination of specialization and integration, the combination of public welfare and marketization, the combination of real estate sales and diversified business, and the combination of independent management and cooperative management should be emphasized in the marketization strategy. In literature [24], through the method of big data analysis, the current old-age policy is not working well at present, the change of family structure has a double influence on old-age care, and the existing old-age care in rural areas is still dominated by families, so the old-age care in rural areas during the social transformation period needs policy support. In literature [25], building and optimizing the pension industry chain is an effective way to promote the healthy and long-term development of China's pension industry, and the key lies in the optimization and integration of the pension industry chain. At present, the definition of industrial chain risk has not reached an agreement in domestic and foreign academic circles. However, for the specific industrial chain, scholars have given a definition of industrial chain risk with strong pertinence but narrow applicability. Literature [26] pointed out that the strategy of healthy China and rural revitalization clearly highlighted the concept of coordinated development of healthy old-age care and rural revitalization in the elaboration of the implementation framework of the two strategies. In literature [27], through the big data analysis method, China has been involved in a serious wave of aging, the number of the elderly population is increasing at an unprecedented rate, and the existing elderly care institutions are far from the actual elderly care service expectations of the people in terms of number and service quality. How to collect the actual needs of the elderly population has become one of the difficulties in implementing such a platform. Literature [28] pointed out that the disadvantages of the traditional pension model are becoming more and more obvious. In order to make the long-term development of China's pension reduce the heavier pension burden of governments at all levels, we must explore a new pension model. Literature [28] stated that the construction of leisure agriculture and rural tourism provides better methods for elderly care services. In literature [29], through the big data analysis method, the current willingness of the elderly to choose elderly care institutions for the elderly shows an increasing trend. It is considered that the reasons restricting the economic growth of China's pension institution industrial chain include income level and capital source. The effective way of economic growth of pension institution industrial chain in the future should take the road of industrialization development. Literature [30] showed the agricultural development of the central region, analyzed the main problems and obstacles it faces, advocated the establishment of a reasonable responsibility-sharing mechanism to support the development of agricultural product processing industry, improved rural infrastructure construction, and realized the sustainable and stable development of agriculture. Literature [31] pointed out that for the elderly lifestyle, old customers mostly choose apartments or elderly care centers, followed by hotels and restaurants, which is related to the frugal consumption mentality of the elderly.

3. Constrained Clustering Algorithm

3.1. Definition of Constrained Clustering. Constrained clustering refers to a method in which specific domain knowledge is expressed in the form of "constraints" and embedded in the clustering process. $\mathrm{CCD}_{\mathrm{default}}$ refers to the updated value, that is, the updated value of enterprise industrial chain tightness calculated regularly through supply chain relevance, enterprise chain relevance, value chain relevance, and spatial chain relevance $(Cl_1, Cl_2, \ldots, Cl_k)$, so that the objective function $\mathrm{DISP} = \sum_{i=1}^{k} \mathrm{disp}\,(Cl_i, \mathrm{rep}_i)$ is the smallest, and each class satisfies constraint c. Among them, $\mathrm{disp}(Cl_i, \mathrm{rep}_i)$ is defined as $\sum_{p \in Cli} df\,(p, \mathrm{rep}_i)$.

According to the rural ecology, the algorithm formula of correlation degree of pension industry chain is deduced as follows:

$$\begin{aligned}\mathrm{OCD} = \mathrm{CCD}_{\mathrm{default}} + \mathrm{CCD}_{\mathrm{default}} = \mathrm{CCD}_{\mathrm{default}} \\ + f\,(\mathrm{SCD}, \mathrm{ECD}, \mathrm{VCD}, \mathrm{RCD}).\end{aligned} \tag{1}$$

$\mathrm{CCD}_{\mathrm{default}}$ refers to the default value, that is, the initial value of the algorithm calculated according to the basic information of the enterprise. $\mathrm{CCD}_{\mathrm{default}}$ refers to the updated value, that is, the updated value of enterprise industrial chain tightness calculated regularly through supply chain relevance, enterprise chain relevance, value chain relevance, and spatial chain relevance. According to the above $\mathrm{CCD}_{\mathrm{default}}$ calculation principle, the $\mathrm{CCD}_{\mathrm{default}}$ decomposition formula is derived as follows:

$$\mathrm{CCD}_{\mathrm{default}} = \sum_{i=1}^{n} B_i \times W_i, \tag{2}$$

where n represents the amount of enterprise basic resource information involved in the calculation; it means the evaluation parameter calculated by the Ith basic resource information of B_i according to the set judgment conditions, which should meet $0 \leq B_i, \leq 1$. It indicates the importance percentage of the Ith basic resource information in the basic information of the enterprise. All the importance percentages must meet the following conditions: $0 \leq W_i \leq 1$, $W_1 + W_2 + \cdots + W_n = 1$.

According to the above description of the four dimensions of the industrial chain, $\mathrm{CCD}_{\mathrm{default}}$ is composed of four basic parameter combinations: SCD, ECD, VCD, and RCD. Set the importance percentage of these four basic parameters in $\mathrm{CCD}_{\mathrm{default}}$ as $\alpha, \beta, \gamma, \vartheta$, respectively, and then use the following formula

$\mathrm{CCD}_{\mathrm{update}}$ can be derived as follows:

$$\begin{aligned}CCD_{\mathrm{update}} &= f\,(SC\,D, EC\,D, VC\,D, RC\,D) \\ &= \alpha \times SC\,D + \beta \times EC\,D + \gamma \times VC\,D + \vartheta \times RC\,D.\end{aligned} \tag{3}$$

$\alpha, \beta, \gamma, \vartheta$ shall meet the following conditions: $0 \leq \alpha, \beta, \gamma, \vartheta \leq 1$, $\alpha + \beta + \gamma + \vartheta = 1$.

Constrained clustering algorithm has made progress in solving scalability, but these features are not available in clustering algorithms in the field of statistics or machine learning. It is a hybrid clustering method based on grid and density, which better meets the above requirements. In a high-dimensional space, it can effectively cluster and find clusters nested in the subspace of high-dimensional data space. The basic idea of the algorithm is to combine the constraint condition with the antimonotone property of the constrained clustering algorithm and jointly use it to prune the candidate clusters, reduce the blindness in the searching process of the constrained clustering algorithm, and improve its efficiency and clustering quality. The general framework of the algorithm is shown in Figure 1.

Constraints, for instance, pairs, can be determined by parameters (Con = : Must-Link constraint set, con ≠: cannot-link constraint set). For example, in pair constraints, the basic idea of constraint clustering algorithm is as follows:

(i) Firstly, scan the dataset D and cluster it on K 1-dimensional spaces
(ii) Select dimension $D_{\min}$ with the smallest number of classes in K 1-spaces
(iii) The condition dense elements on $D_{\min}$ are obtained by imposing constraints on $D_{\min}$
(iv) Candidate dense cells are generated by using conditional dense cells on attribute $D_{\min}$ and other dense cells in $(k-1)$ 1-dimensional spaces
(v) The following steps are the same as those of the constrained clustering algorithm

3.2. Constraint Types and Algorithms. Domain knowledge is a very big concept, and there is almost no unified expression form. It can be expressed in various forms. In addition to the guidance form of "class label," there is information about the structure of the problem, heuristic guidance rules, the relationship between data objects, or the combination of the

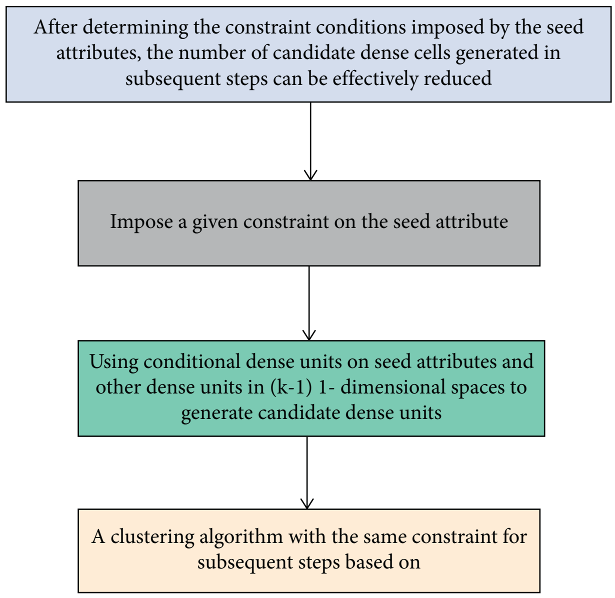

Figure 1: Overall framework of the constrained clustering algorithm.

above forms. The selection of central objects in the constrained clustering algorithm is random. If the randomly selected central objects are concentrated, the number of iterations to form the final partition may be increased, which affects the clustering speed. Therefore, selecting an appropriate central object can speed up the convergence of the algorithm. Since all spatial objects have spatial relationships, the appropriate central object can be selected according to the directional relationship of the residential object. According to the constraint clustering algorithm and matching algorithm, the association compactness of the pension industry chain is sorted from high to bottom. The ranking results of the association compactness of the pension industry chain are shown in Figure 2.

Then, combined with the enterprise reputation model, the optimized constrained clustering algorithm is used to calculate the association tightness of the elderly care industry chain. The numerical comparative analysis results before and after are shown in Figure 3.

Our algorithm is based on a mathematical morphology clustering algorithm. The obstacle constraint and the idea of dealing with the obstacle constraint are introduced. It not only has the advantages of a mathematical morphology clustering algorithm but also has low complexity. It can find clusters of arbitrary shapes. Moreover, the data on both sides of the obstacle can be effectively divided into different classes. The algorithm involves linear obstacles in two-dimensional space, and planar obstacles are considered as polygons surrounded by multiple linear obstacles. According to the scope of objects imposed by constraints, it can be divided into the following four categories:

(i) Global-level constraints work on the data objects participating in clustering.

(ii) Cluster-level constraints are constraints for each class, such as the number of data points owned in each class.

(iii) Feature-level constraint is a constraint applied to the features describing data. When the features meet certain conditions, some rules are enabled.

(iv) Instance-level constraints are for data objects or constraints between data objects.

4. Necessity of Transformation and Optimization of Pension Industry Chain

4.1. Definition of Constrained Clustering. With the increasing aging of the population, however, the contradiction between the growing demand for the aged and the traditional family pension has become increasingly prominent due to the change of family structure and the acceleration of population mobility. In the traditional old-age care service industry, public old-age care institutions are supported by the government's financial support, forming a situation of long-term dependence on the government, which is often only targeted at specific subsidy groups. The institutional old-age care model can no longer meet the needs of the elderly, and the ecological old-age care model will become the development trend. The old-age care industry provides professional social services for the elderly at home to meet the diversified needs of the old-age care services. However, with the increase of the immunization rate, the reduction rate of the spread range has dropped all the way, especially when the proportion of the node enterprises implementing immunization exceeds 0.08, the reduction rate of the spread range has obviously slowed down. As shown in the figure, the risk spread range caused by $h = 08.0$, $h = 1.0$, and $h = 12.0$ has little difference. It can be seen that there is a threshold value for the proportion of immune enterprises when implementing the target immunization strategy for key node enterprises. In the aging population, accelerating family structure, and population mobility, the contradiction between the ever-increasing needs of providing for the aged and family support has become increasingly prominent. Social institutions for the aging population have been unable to meet the needs of providing for the elderly, and the way of providing for the aged population at home will become the future development trend. A municipal committee on aging released an analysis report chart of the aging situation of a certain population from 2015 to 2020. The latest data show that as of the end of 2019, the aging population in a certain city has increased the most. as shown in Figure 4.

According to the statistics in the table, the city has already entered an aging society, and the degree of aging is gradually deepening. The problem of population aging has profoundly impacted the social life, economic development, and cultural development of Wuhan. At the same time, it also puts forward tests and requirements for the social welfare and security system. Positive measures must be taken in the fields of pension medical care and pension insurance, and pension culture. In the process of sustainable social and economic development, transforming and optimizing industries can drive other industries in society. The pension industry intersects with many industries. For the special consumer groups of the elderly, the development of the pension industry can not only meet the pension needs of the elderly but also effectively stimulate domestic demand. The

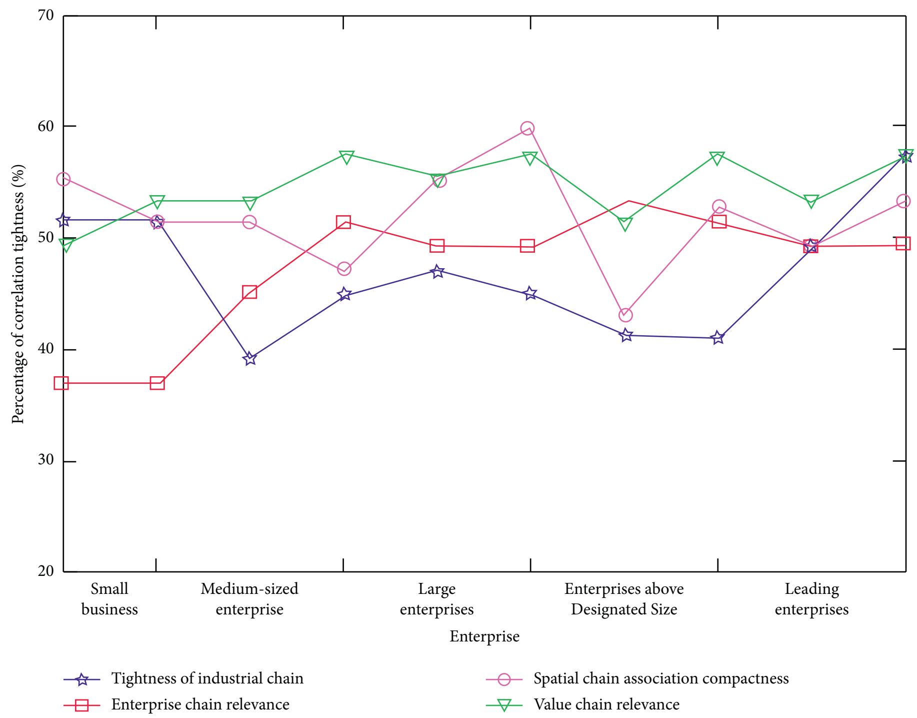

Figure 2: Ranking diagram of correlation degree of pension industry chain obtained by the constrained clustering algorithm.

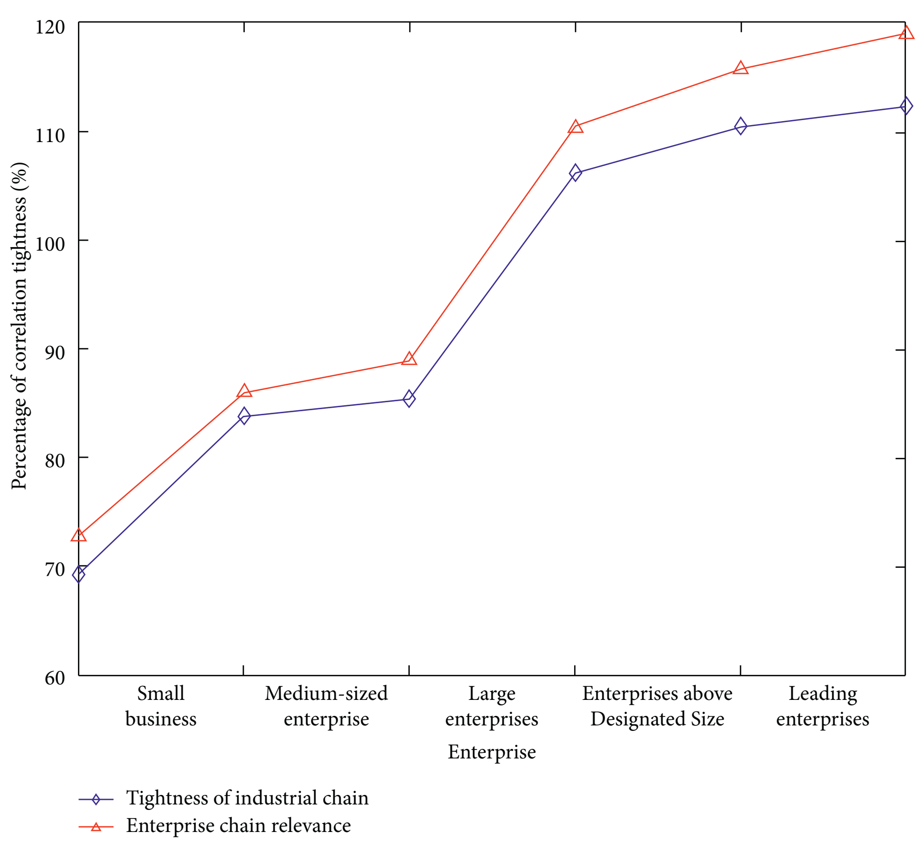

Figure 3: Comparison chart of correlation degree of pension industry chain before and after optimization.

change of risk propagation range of complex network of rural ecological elderly care industry chain based on target immunity and random immunity is shown in Figure 5.

It can be seen that the scope of risk spread has obviously shrunk after targeted immunization of industrial chain networks, with an average drop of more than 26%. However,

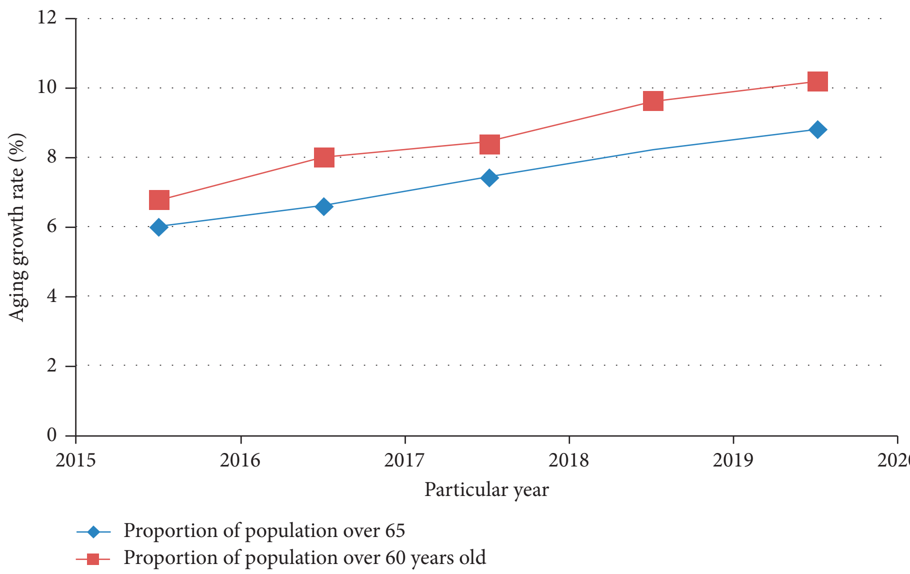

FIGURE 4: Population aging growth rate of a city.

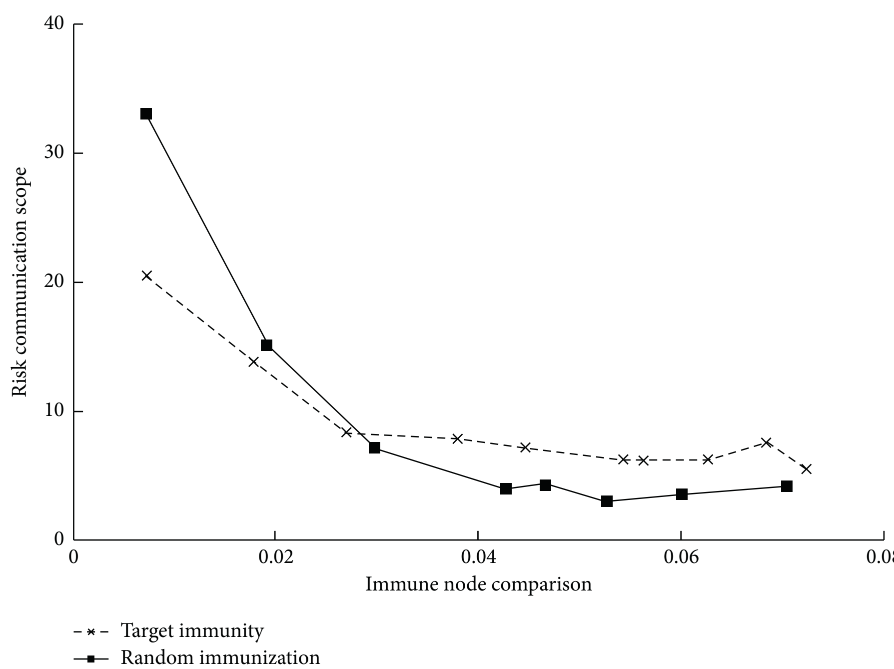

FIGURE 5: Change of risk transmission effect of pension industry chain under target immunization.

with the increase of the immunization rate, the reduction rate of the spread range has dropped all the way; especially when the proportion of the node enterprises implementing immunization exceeds 0.08, the reduction rate of the spread range has obviously slowed down. As shown in the figure, the risk spread range caused by $h = 08.0$, $h = 1.0$, and $h = 12.0$ has little difference. It can be seen that there is a threshold value for the proportion of immune enterprises when implementing the target immunization strategy for key node enterprises. When the proportion of immune enterprises is less than the threshold value, the control effect of industrial chain risk transmission is very obvious with the increase of the proportion. When the proportion of immune enterprises is greater than the threshold value, increasing the immune enterprises does not cause a significant reduction in the scope of risk transmission.

Private old-age care institutions built by social forces are difficult to maintain and operate, with few sources of funds, low profits, and no good industrialization form. The transformation and optimization of the old-age care industry should be accelerated, and high-quality life products and services for the elderly should be better provided. Comparatively speaking, the investment risk of social capital is relatively high, and a complete mature model of investment in old-age care institutions has not yet been formed, and most of the capital is still on the sidelines, which makes it difficult for the government to really implement measures to encourage social forces to enter the old-age care industry.

4.2. The Need to Promote Sustainable Socioeconomic Development. The transformation and optimization of the old-age care industry are critical engines for future economic growth, with a significant economic driving effect. The old-age care industry is a sunrise industry with many industries, and the old-age care industry's market supply system, which is generated by the satisfaction of six "old-age" needs, has a lot of room for growth. The old-age care industry has its own unique characteristics, and its core components are old-age care services and old-age care products, and the old-age care industry chain is comprised of many aspects of economy and society, a long industrial chain, reliance and interaction with the environment, and requirements for sustainable development. In a market economy, vigorously developing the pension industry is an unavoidable requirement for the development of population aging. The retirement industry will usher in a new era of rapid growth. As an emerging industry, The pension industry is critical to adjusting the industrial structure, improving employment rates, promoting coordinated economic and social development, and improving the socialist market economy. The chain of ecological pensions is usually in a state of rapid development. Although the market has recognized new products to some extent, more capital investment and technological advancement are still required to expand market share. Figure 6 depicts the parameters.

Let $U = [\mu_{ik}]_{c\times n}$ be a hard partition matrix, where C is the number of clusters, which is the number of samples. The cluster center point set of a partition $P=\{P_1, P_2, \ldots, P_C\}$. According to the sample division method, then

$$\mu_{ik} = \begin{cases} 1, & d_{pik} = \min\left\{d_{p1k}, d_{p2k}, \ldots, d_{pck}\right\}, \\ 0, & \text{Other}, \end{cases} \quad k = 1, 2, \ldots, n; \quad i = 1, 2, \ldots, c, \tag{4}$$

where d_{Pik} is the reachable distance between the sample X_k in class I and the center point pi of class I. If the sum of within-class squared errors (WGSE) is used as the clustering objective function, then the clustering objective function is as follows:

$$f(U, P) = \sum_{k=1}^{n}\sum_{i=1}^{c}\mu_{ik}\left(d_{pik}\right)^2. \tag{5}$$

If the natural coding scheme is adopted, the volume coding is

$$b = \left\{\text{Num}_{p1}, \text{Num}_{p2}, \ldots, \text{Num}p_{pi}, \ldots, \text{Num}_{pc}\right\}, \tag{6}$$

where $\text{Num}_{pi}\,(1 \le \text{Num}_{pi} \le n)$ means that the cluster center $p_i\,(i = 1, 2, \ldots, c)$ is taken from the Num_{pi} sample in the sample set. According to our knowledge of analytic geometry, the edges (x_i, x_j) and edges $(y_{km}, y_k(m+1))$ meet the following conditions:

$$\begin{cases} \left(a_l \times y_{kml} + b_{lkm2} + c_1\right) \times \left(\alpha_1 \times y_{k(m+1)l} + b_{lyk(m+1)2} + C_1\right) < 0, \\ \left(a_2 \times x_{i1} + b_2 x_{i2} + c_2\right) \times \left(\alpha_2 \times x_{j1} + b_2 x_{j2} + c2\right) < 0. \end{cases} \tag{7}$$

Based on the matching model of the same evaluation index, the following mathematical model is established:

$$\max \sum_{i=1}^{I}\sum_{j=1}^{J}\alpha_{ij} * x_{ij} + \sum_{i=1}^{I}\sum_{j=1}^{J}\beta_{ij} * x_{ij}, \tag{8}$$

$$0 < \sum_{j=1}^{I} x_{ij} \le p_i, \forall_i, j, \tag{9}$$

$$0 < \sum_{i=1}^{I} xi_j \le q_j, \forall i, j. \tag{10}$$

In the above model, (8) is the objective function, which means to maximize the total matching degree of matching parties as much as possible. Formula (9) means that the caregiver I matches pi loved ones at most. Formula (10) means that the cared-for j matches q_j caregivers at most. Moreover, (4) is a 0-1 decision variable.

Compared with the traditional elderly care industry, the ecological elderly care industry is a new industry that gives full play to the ecological advantages of resources and environment so as to meet the needs of elderly care and leisure services. This kind of industry has the characteristics of low-carbon and environmental protection. Through appropriate government guidance and policy support, the development of the pension industry is bound to inject new vitality into China's current economic development, promote new growth of the national economy, and further promote the sustainable development of the current economy and society.

4.3. The Need to Improve the Level and Efficiency of the Aged Care Service Industry. The development of China's pension industry lags behind, the supply of pension products and services is insufficient, and the pension industry chain is immature. Therefore, the transformation and optimization of the pension industry are imperative. It can be seen that the scope of risk spread has obviously shrunk after targeted immunization of industrial chain networks, with an average drop of more than 26%. In addition, the elderly care service is inseparable from the care and greetings of the elderly. When the proportion of immune enterprises is less than the

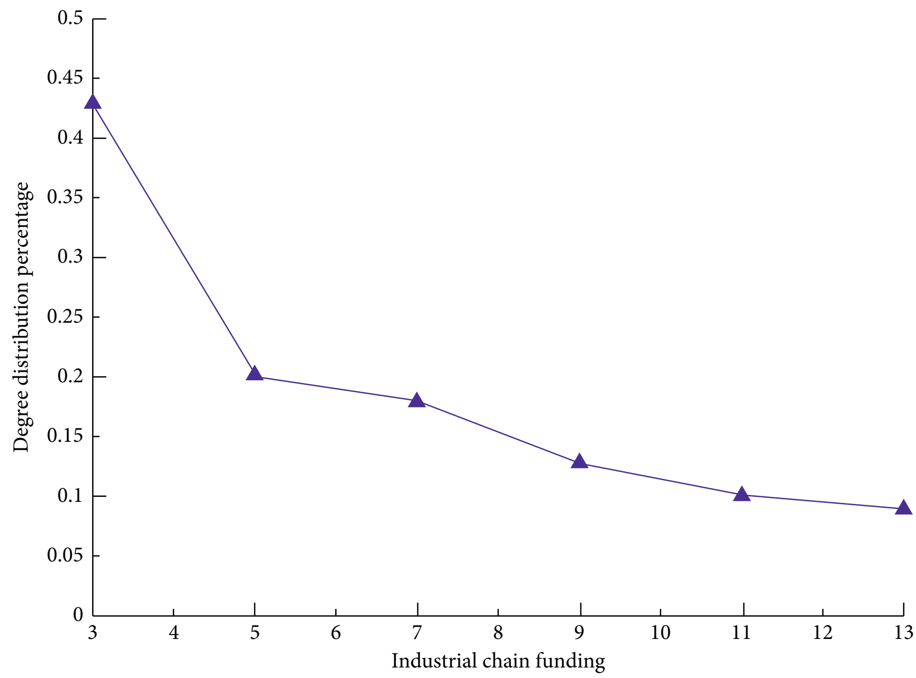

Figure 6: Distribution chart of capital change degree of the ecological pension industry chain.

threshold value, the control effect of industrial chain risk transmission is very obvious with the increase of the proportion. In the care greeting network, both the caring person and the cared person contain multiple matching indicators. Under the centralized construction mode of care greeting network, matching is carried out according to the indicators of the caring person and the cared person, so as to achieve the overall optimal goal of the network. In the network of caring and greeting, the main consideration is the matching between the caring person and the cared person. There are both the same matching indicators and different matching indicators between them, as shown in Figure 7.

Matching indicators of loved ones are educational background, work experience, geographical location, and service demand. Caregiver matching indicators are educational background, work experience, geographical location, knowledge, and skills. In the process of matching, each matching index is matched in one-to-one correspondence, in which the service needs of the loved ones are matched with the knowledge and skills of the loved ones.

According to the educational background, match the schools of the caregivers and the loved ones, take the names of different schools as the matching basis, and calculate the number of schools where the two sides have the same attendance so as to determine the matching degree. In the care and greeting network, caregivers and loved ones continue to join through the network platform, and we are concerned about how to reasonably match them. In the matching process, taking the optimal overall matching degree as the goal, under multiple matching indexes, the matching degree between matching objects is calculated according to the individual preference of matching objects, and then the connection between them is established intensively. In the care and greeting network, it is assumed that there are six caregivers and six loved ones. The maximum matching number of caregivers is 3 and the maximum matching number of loved ones is 6. The matching degree between caregivers and loved ones is shown in Figure 8.

From the perspective of the industrial chain, such distribution characteristics reflect the following. (1) There is no significant difference in the number of partners between node enterprises, which means that although a small number of core enterprises with comparative advantages have been formed in the industrial chain, this advantage is not obvious. (2) There are a large number of enterprises with a medium competitive advantage, and some of them may stand out and become industry leaders. (3) The number of enterprises in the third echelon is small, and there are mainly two types. First, enterprises or institutions with special properties, such as product certification bodies, mainly provide certification services for a small number of enterprises, so there are fewer partners in a single industrial chain. Second, the backward enterprises in the industrial chain, whose development scale is small and the speed is slow, cannot win a large number of partners and are likely to be eliminated in the competition, as shown in Figure 9.

By sorting out the factors that affect the industry consolidation for the aged population, this article sets six potential variables that can not be directly observed, namely, the environment of the aged care service, the demand structure of the aged group, the management of the aged care service, the intelligent aged care service system, the development status of the intelligent aged care industry, and the service feedback effect. Each potential variable is represented by a group of significant observable variables, with a total of 16 significant variables. The theoretical framework of

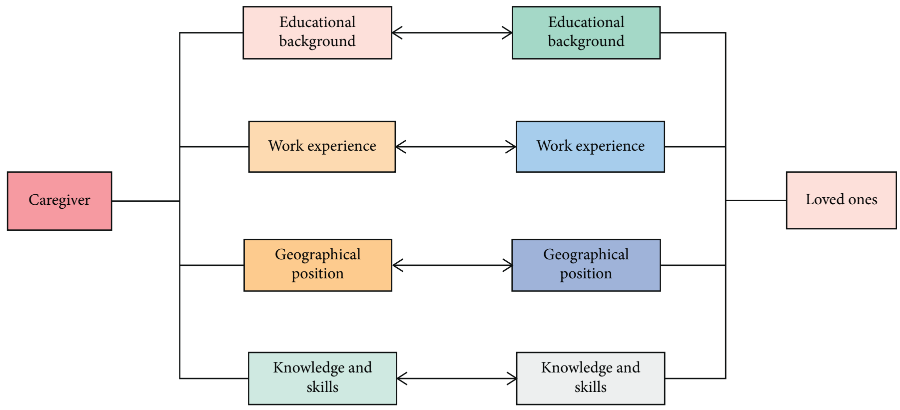

FIGURE 7: Matching relationship of network indicators.

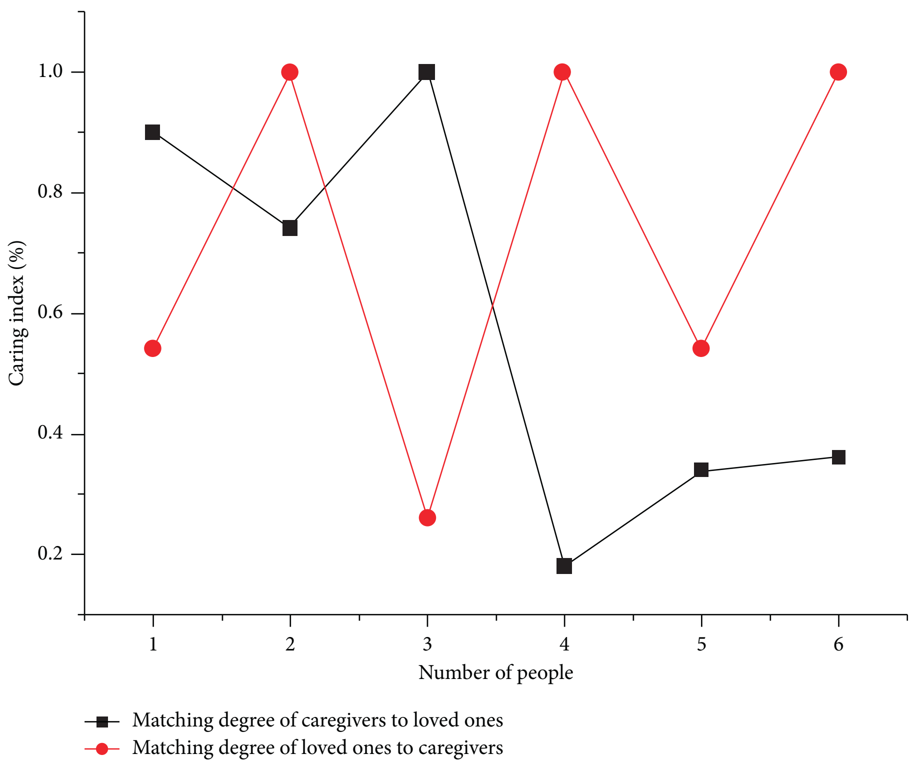

FIGURE 8: The matching degree between the caregiver and the loved one.

"triple functional relationship" mainly refers to the analysis framework of the influencing factors of the industry consolidation of smart pension, as shown in Figure 10.

With the increasingly prominent problem of population aging, it is necessary to promote the modernization, scale, industrialization, specialization, and institutionalization transformation of traditional aged care services, from the government to the combination of government-led and market-oriented mechanisms and from the traditional low-level aged care services to the high-level aged care services. Farmers should be encouraged to implement land circulation and form agricultural cooperatives through various forms such as joint ventures and shareholding so as to make full use of local ecological advantages and make use of idle land. The transformation and optimization of the old-age care industry should be accelerated, and high-quality life products and services for the elderly should be better provided. It is important to carry out investment attraction, establish a special management committee, reasonably allocate and coordinate relevant resources, and carry out

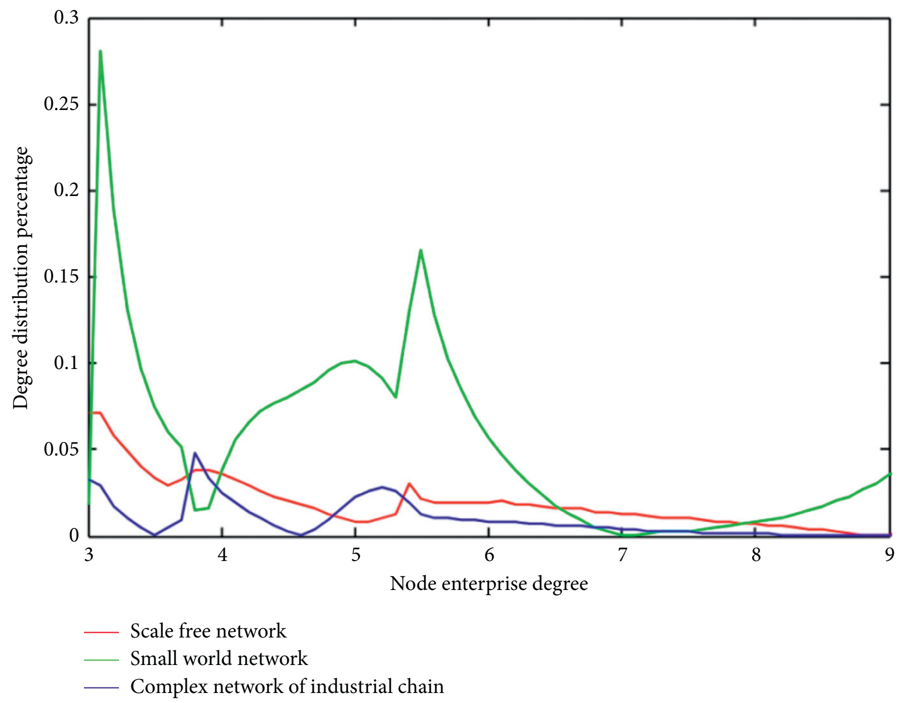

Figure 9: Degree distribution of three network structures.

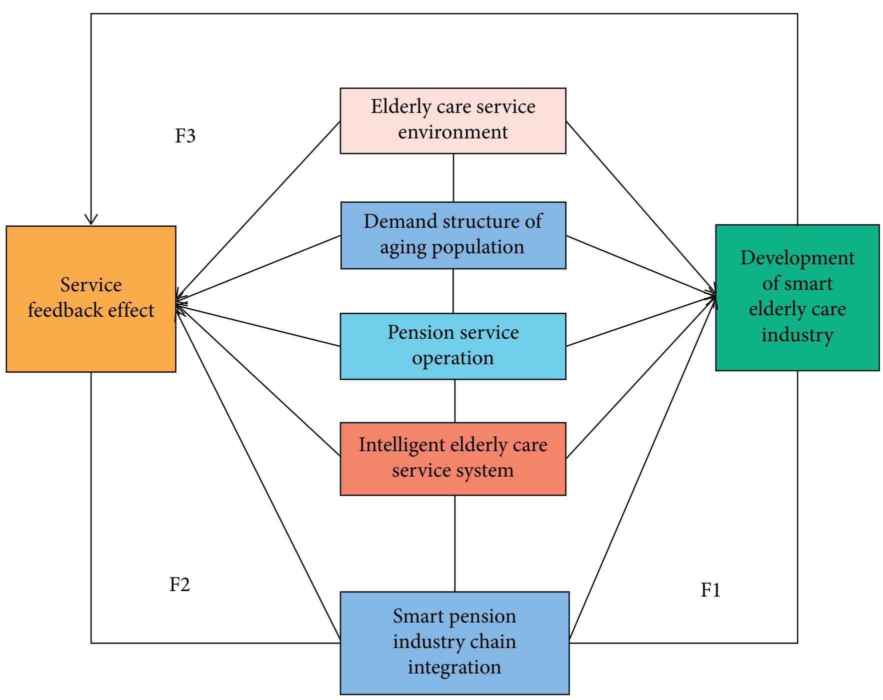

Figure 10: Theoretical framework of "triple function relationship" of influencing factors of pension industry chain integration.

classified management. Farmers can operate some small farmhouses, and enterprises can invest in large sightseeing parks.

5. Conclusions

In a word, in the process of increasing the social aging population, strengthening the transformation and development of elderly products is of great significance to the safe and stable development of the whole society and effectively promotes the development of the social economy. This article studies the effectiveness and importance of constrained clustering algorithms in the transformation and optimization of rural ecological elderly care industrial chains. The choice of ecological pension industry model is one of the frontier issues in the economic theory research of the pension industry, and the research on the implementation path of rural revitalization is the main focus of the development theory research of "agriculture, rural areas, and farmers." Private old-age care institutions built by social forces are difficult to maintain and operate, with few sources of funds, low profits and no good industrialization form. At present, the academic circles have made some progress in researching the mode selection of the ecological pension industry. Although scholars have different opinions on the specific mode selection, they have reached a consensus in some aspects. As the ecological pension industry is a new industrial form in China, and the rural revitalization strategy has only been put forward in recent years and the research on it by domestic scholars is extremely limited and is still in the primary exploration stage. The effective use of background knowledge can make the constrained clustering algorithm obtain more heuristic information to reduce the blindness in the search process and improve the efficiency and clustering quality of the algorithm. This article describes in detail the role and advantages of the constrained clustering algorithm in transforming the rural ecological elderly care industrial chain. At the same time, we should also strengthen the supervision of various forms of community pension models such as private and public assistance, public construction, and private and public construction. In the process of supervising these forms of old-age care, we also need to pay attention to matters such as staffing, investment and use of government funds, and service quality.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Evaluation Model of Online and Offline Mixed Teaching Quality in Colleges and Universities Based on BP Neural Network

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Hybrid online and offline teaching is becoming the mainstream teaching method in the postepidemic era. However, research on assessing its teaching quality is still limited. This article thus develops a teaching quality evaluation model based on the BP neural network. A three-dimensional indicator system involving 19 indicators is set in the model. The established model was demonstrated and validated by a case study. The results show that the developed model can accurately assess the teaching quality of hybrid online and offline teaching. Findings from this study can provide valuable references for improving the quality of hybrid online and offline teaching.

1. Introduction

In the digital era, digital technologies represented by the new generation of Internet technology have significantly reduced the cost of information dissemination. Students can, therefore, easily access a vast amount of high-quality teaching resources through the Internet. In this context, both "teaching" and "learning" are given a new connotation of the times [1]. A lot of online teaching platforms like Coursera, Udacity, and edX have emerged. More and more schools, including some top universities like Harvard and MIT, have opened their public courses. Online teaching is beginning to be accepted by the public and is increasing [2]. Especially in the wake of the 2020 New Crown Pneumonia outbreak in countries around the world, online teaching has become a choice many universities have to make in the context of epidemic prevention and control [3]. Even though the epidemic has been initially controlled in some countries and regions, the situation of epidemic prevention and control is still very serious [4]. At present, more and more universities select hybrid online and offline teaching for daily teaching tasks, such as Hong Kong Polytechnic University, Sydney university, and so on. The Ministry of Education has issued policy documents such as "Action Plan of Education Informatization 2.0" and "Opinions on Strengthening the Application and Management of Online Open Courses in Higher Education Institutions." And at the same time, the Ministry of Education has held a series of meetings such as the "National Conference on Higher Undergraduate Education in the New Era" to promote the construction of online resources of various courses [5]. It encourages universities to actively build online resources of multiple classes and promote the deep integration of modern information technology and education [6]. In November 2020, the first batch of 5118 national first-class undergraduate courses, including 868 online and offline hybrid first-class courses, was launched. Facing the new challenges in the postepidemic era, the large-scale hybrid online and offline teaching tends to become the mainstream mode of teaching in the future [7].

Even though the mode of hybrid online and offline teaching has obtained certain development and achievements, there are still many teachers, students, and experts who doubt that the online and offline hybrid teaching mode cannot achieve the expected teaching effect and thus negatively affect the personnel training of the universities. Prospective research on the evaluation of teaching quality of hybrid online and offline teaching is apparent [8]. However, at present, systematic and comprehensive assessment indicators and approaches are unavailable.

To address the research gap, this study proposes a process model and develops an indicator system for assessing the teaching quality of hybrid online and offline teaching from the perspective of the whole process of curriculum construction, teaching implementation, and teaching effects. An evaluation model based on BP neural network is also developed. A lecture called Introduction to Machine Learning in a university in Shanxi, China, is selected for a case study to demonstrate and validate the established model. On the one hand, findings from this study can make up for the deficiency of emphasizing teaching process evaluation rather than course evaluation in current research on hybrid teaching quality evaluation. On the other hand, it provides suggestions and improvement direction for similar colleges to perfect the construction of related curriculums and improve the quality of hybrid online and offline teaching.

2. Related Works

From the late 1990s to the present, scholars have experienced three stages of technology-centered, teacher-centered, and student-centered cognition of hybrid teaching, which is a teaching mode combining online and offline teaching. Most scholars believe that the online part of blended teaching includes MOOC teaching, SPOC teaching, APP teaching, and other forms [9, 10], and the offline part is mainly face-to-face teaching in classrooms, but the application of modern digital technology should be emphasized. Baragash and Al-Samarraie conducted a large-scale survey on perceptions of hybrid teaching and learning in US colleges and universities [11]. They found that faculty perceptions of hybrid teaching and learning have moved beyond technology integration to a higher level of content and effectiveness improvement. Laura et al. suggest that teachers and students derive greater psychological satisfaction from hybrid online and offline teaching than from traditional instructional programs based on cognitive theory [12]. Furnes et al. found that a 2-year follow-up study of a hybrid online and offline teaching program for undergraduate students at the University of Miami [13]. They also found that the hybrid online and offline teaching program significantly improved students' communication and innovation skills and was a highly effective teaching model.

Teaching quality is a direct reflection of the effect of educational activities [13, 14], and global scholars have conducted a lot of research on teaching quality evaluation, covering various aspects, such as influencing factors, dimension classification, evaluation indexes, and methods [15–19]. In terms of factors influencing online teaching quality, Xu et al. identified interaction (including the interaction between students, the interaction between students and teachers, and the interaction between students and contents), online self-efficacy, and self-regulated learning habit as essential factors influencing the quality of hybrid online and offline teaching for university students [20]. In terms of hybrid teaching quality dimension division, Huang et al. pointed out that during the new crown pneumonia epidemic, the construction of an online teaching quality assurance system in national universities showed comprehensive, diversified features from three dimensions of supervisors, teachers, and students [21]. Scholars have also proposed using big data methods and machine learning methods to convert macroscopic, qualitative evaluation to microscopic, quantitative evaluation [19, 22, 23].

In summary, in the face of the rapid advancement of digital technologies and the impact of the new coronary pneumonia epidemic, worldwide scholars continue to be enthusiastic about hybrid online and offline teaching and learning and have achieved specific achievements in the research of hybrid online and offline teaching quality assessment. However, there are still the following deficiencies:

(1) The hybrid online and offline teaching mode is becoming more affluent, especially with the development of mobile Internet, which further promotes the diversification of hybrid online and offline teaching. But the current research on the evaluation of hybrid online and offline teaching quality has not yet paid attention to this new change.
(2) The existing research on the quality of hybrid online and offline teaching mainly starts from the perspective of the general process of teaching activities, ignoring the impact of hybrid online and offline teaching courses as the basic unit and new mode teaching mode on educational effects.
(3) The hybrid online and offline teaching quality evaluation indicator system established by the existing research is relatively brief, ignoring the key index points that affect the quality of hybrid teaching, such as course objectives, course philosophy, and teaching team, which affects the completeness of the hybrid teaching quality evaluation system.
(4) The current research on the implementation strategy of hybrid teaching has not yet formed a good echo with the research on teaching quality evaluation, and the suggestions on the implementation strategy of hybrid teaching quality evaluation based on the expansion of practice level will help the application and promotion of the hybrid teaching.

3. Development of Evaluation Indicator System

3.1. Principles. Hybrid online and offline teaching is based on constructivist learning theory and emphasizes student-centeredness. Currently, the development of 5G technology and the popularity of mobile Internet have expanded hybrid teaching to new forms, such as mobile Internet APP, and the basic elements involved in hybrid teaching, such as teaching resources, are also expanding. This paper proposes the principles that should be followed in constructing a hybrid teaching quality evaluation indicator system from the following aspects.

3.1.1. Integration of Course Evaluation and Implementation Evaluation. The quality evaluation system of hybrid online and offline teaching must start from the curriculum as the high level of curriculum is the prerequisite and fundamental to ensure the quality of blended teaching. The prerequisite and foundation for the quality of hybrid online and offline teaching is a high-level curriculum. The evaluation of the implementation and feedback of hybrid teaching is carried out to grasp the fundamental elements of the curriculum in hybrid teaching. The quality evaluation system of hybrid online and offline teaching should be based on the whole teaching process, and the coverage of teaching quality evaluation index points should be improved.

3.1.2. Combination of Process Evaluation and Outcome Evaluation. The student-centered teaching concept requires that the evaluation of hybrid online and offline teaching quality should focus on process evaluation on the one hand and outcome evaluation on the other. The process evaluation needs to focus on the dimensions of teacher-student interaction, student-student interaction, and teaching contents, and its forms include learning behavior evaluation on the desktop and mobile end of the teaching platform, offline learning behavior evaluation, stage assignments, and so on; the form of outcome evaluation includes test papers, essays, defenses, and so on.

3.1.3. Diversification of Evaluation Subjects and Evaluation Indicators. Hybrid online and offline teaching includes both flexible online desktop teaching and mobile APP teaching and traditional offline, face-to-face teaching. Both teachers and students are deeply involved in the whole process of teaching activities, especially in the construction of hybrid teaching courses; the teachers' overall design of the course has an important impact on the teaching quality. Therefore, in the selection of evaluation subjects, teachers, students, and experts inside and outside the university and the teaching platform should be included in the evaluation subjects, and the application of learning behavior data from the desktop and mobile ends of the teaching platform should be emphasized. As for the evaluation indicators, the diversified design of combining qualitative and quantitative indexes, objective data, and subjective judgment should be insisted on.

3.1.4. Comprehensive Evaluation Content and Evaluation Method. As the course construction and organization implementation process in hybrid teaching are relatively complex, the quality evaluation needs to be more comprehensive and detailed, focusing not only on the all-round examination of the course construction but also on the evaluation of questions, tests, and assignments in the traditional offline teaching process, as well as the evaluation of video viewing, chapter tests, topic discussions, and other contents in the online teaching process. In terms of evaluation methods, evaluation can be carried out with the data from the online desktop and mobile APP teaching platforms, and phase evaluation and rolling dynamic evaluation can also be carried out according to the course teaching progress.

3.2. Indicator System. The key to constructing a hybrid teaching quality evaluation system is the selection and determination of evaluation indicators. This paper develops a hybrid teaching quality evaluation system containing three first-level indicators: course construction evaluation, teaching implementation process evaluation, and teaching effect evaluation.

Firstly, in the evaluation of hybrid teaching course construction, combined with the specific elements contained in the course, we focus on whether the system meets the basic construction standards and, at the same time, has the essential characteristics of hybrid teaching. Specifically, seven secondary indicators such as course objectives, teaching content, and teaching design are evaluated comprehensively and should be considered by different evaluation subjects because of the difference in the connotation of secondary indicators of different dimensions. The indicator system is shown in Table 1.

Secondly, in evaluating the teaching implementation process of hybrid teaching, we aim to improve the interactivity and build a teaching process evaluation system based on the interaction between "teaching" and "learning." Specifically, it includes four secondary indicators, namely, students' online session, teachers' online session, students' offline session, and teachers' offline session, as shown in Table 2.

At last, in the evaluation of hybrid teaching effect, the teaching effectiveness of both online teaching and offline classroom is combined to make a comprehensive judgment. Specifically, from two dimensions of process assessment and outcome assessment, eight secondary indicators are designed, including assessment objectives, assessment forms, assessment contents, and assessment quality, as shown in Table 3.

4. Assessment Methods

4.1. Model Development. Traditional assessment methods such as the single-factor evaluation method, the comprehensive evaluation method, fuzzy mathematics, operation research, multivariate statistical analysis, multidimensional scalar analysis, and so on have been used to evaluate the quality of hybrid teaching. Even though these methods could achieve certain results to different degrees, they were imperfect, mainly in the following aspects: (1) It is difficult to determine the weights of each secondary index, and the evaluation is usually subjective and arbitrary by virtue of experts' experience. There is thus a specific error with the actual value. (2) It is difficult to make an accurate evaluation of the results of specific indicators by traditional methods. (3) The calculation is complicated, and the solution is tedious. (4) The algorithm lacks self-learning ability. Therefore, this study tries to obtain a fast, effective, and accurate method of hybrid teaching quality evaluation.

Table 1: Evaluation indicators of hybrid teaching course construction.

Indicators	Subindicators	Meanings	Subjects
Course construction evaluation X1	Course objectives X11	(1) In line with the school's orientation (2) In line with the professional training objectives (3) Covering the three dimensions of knowledge, quality, and ability (4) Reflecting innovation, high order, and challenges	Internal and external experts
	Teaching content X12	(1) Clearly expressed; measurable, quantifiable, and assessable in terms of achievement (2) Implementing the requirements of the construction of curriculum thinking and politics (3) Reflecting the frontier and modernity (4) Reflecting the integration of multiple disciplines (5) Meeting the teaching objectives	Internal and external experts
	Teaching design X13	(1) Reasonable arrangement of online and offline teaching hours (2) The online and offline teaching contents are cross-complementary (3) Close connection between online and offline teaching activities	Internal and external experts
	Teaching team X14	(1) Upholding the concept of student-centered, output-oriented, and continuous improvement (2) Strong awareness of teaching reform and outstanding teaching ability (3) Clear division of labor and mutual collaboration	Internal and external experts
	Teaching resource X15	(1) In line with the teaching objectives (2) Teaching resources are abundant in various forms (3) Teaching resources are updated in a timely manner and have a short periodicity	Internal and external experts
	Teaching platform X16	(1) Easy and fast operation of the platform and stable operation (2) Instant monitoring, feedback, and statistics (3) Convenient interaction between teachers and students, students and students in various forms (4) Supporting for a variety of functions, such as testing, assessment, and live streaming (5) Facilitating teachers' personalized teaching design and students' personalized learning	Teachers and students
	Teaching environment X17	(1) Software and hardware configurations to meet teaching needs (2) Stable network environment (3) Supporting new technologies and tools	Teachers and students

Artificial Neural Network, in the field of machine learning and cognitive science, is a mathematical or computational model that mimics the structure and function of biological neural networks (the central nervous system of animals, especially the brain) for estimation or approximation of functions [24]. A neural network consists of a large number of artificial neurons linked for computation. In most cases, artificial neural networks are able to change their internal structure based on external information and are adaptive systems, which are commonly known as having a learning function. Modern neural networks are a nonlinear statistical data modeling tool, and they are usually optimized by a learning method based on a mathematical, statistical type, so they are also a practical application of mathematical, statistical methods, which allow us to obtain a large number of local structural spaces that can be expressed as functions [25, 26]. On the other hand, in the field of artificial perception in artificial intelligence, we can do decision problems in artificial perception through the application of mathematical statistics (i.e., through statistical methods, artificial neural networks can have the ability to make simple decisions and superficial judgments like human beings), and this method has advantages over formal logical reasoning [27]. Like other machine learning methods, neural networks have been used to solve a wide variety of problems, such as machine vision and speech recognition. These are problems that are difficult to be solved by traditional rule-based programming.

BP neural network, also called "error backpropagation neural network," provides a novel technique for teaching quality evaluation, which can effectively overcome the shortcomings of traditional evaluation methods. In essence, this is a category of dynamic information processing systems composed of a large number of information processing units through a wide range of linkages, and this system is unique in processing various kinds of paradoxical, ambiguous, random, large volumes dynamic, and low-precision information. It has the functions of learning, remembering,

Table 2: Evaluation indicators of hybrid teaching implementation process evaluation.

Indicators	Subindicators	Meanings	Subjects
Teaching implementation process evaluation X2	Students' online session X21	(1) Length of students' study (2) The number of times of students' study (3) Percentage of students completing task points (4) Students' online chapter test scores (5) The number of times of students extending their learning (6) The number of times of students participate in activities (7) The number of times of students post and reply to posts (8) The degree of completion of student group tasks (9) Quality of student group task completion	Platform and teachers
	Teachers' online session X22	(1) The number of teacher postings (2) The number of times of teachers answering questions (3) Coverage rate of teachers' Q&A (4) The time limit for teachers to answer questions (5) The number of times of teachers guided, supervised and instructed students in their studies (6) The number of teaching activities organized by teachers	Platform and students
	Students' offline session X23	(1) The number of times of students asking or answering questions (2) The quality of questions asked or answered by students (3) The number of times of students participated in classroom activities (4) The student's performance in completing classroom tests (5) The clear division of work among group members (6) The degree of completion of group tasks (7) Quality of group tasks completed	Platform and teachers
	Teachers' offline session X24	(1) The number of questions asked by teachers (2) The organization of classroom activities by teachers (3) Development of team learning by teachers (4) Experiential learning by teachers (5) The conduct of classroom tests by teachers (6) Training students to solve complex problems (7) Teaching with digital teaching tools (8) Teachers' guidance to students (8) Teachers guide students in learning, summarizing, and reflecting on the situation	Platform and students

Table 3: Evaluation indicators of hybrid teaching effect evaluation.

Indicators	Subindicators	Meanings	Subjects
Teaching effect evaluation X31	Objective of process evaluation X31	Covering milestones	Internal and external experts
	Form of process evaluation X32	Nonstandardized evaluation	Internal and external experts
	Content of process evaluation X33	(1) Evaluation of course knowledge (2) Evaluation of professional skills (3) Evaluation of applied skills (4) Comprehensive ability evaluation (5) Competence evaluation	Internal and external experts
	Quality of process evaluation X34	Evaluation quality	Teachers
	Objective of outcome evaluation X35	Covering milestones	Internal and external experts
	Form of outcome evaluation X36	Nonstandardized evaluation	Internal and external experts
	Content of outcome evaluation X37	(1) Evaluation of course knowledge (2) Evaluation of professional skills (3) Evaluation of applied skills (4) Comprehensive ability evaluation (5) Competence evaluation	Internal and external experts
	Quality of outcome evaluation X38	Evaluation quality	Teachers

associating, summarizing, generalizing, extracting, guest error, and self-adaptive capabilities and is a system that can handle nonlinear problems.

A typical BP neural network is a three-layer feed-forward hierarchical network consisting of an input layer, an implicit layer, and an output layer. The learning process of a BP neural network consists of forwarding propagation of information and backward propagation of errors. When given a set of input patterns to the network, the BP network will sequentially learn this set of input patterns in turn in the following manner: first, the input pattern is transmitted from the input layer to the implicit layer unit, and after being processed by the implicit layer unit layer by layer, an input pattern is generated and transmitted to the output layer, which is called forward propagation [28]. The output result is then compared with the expected value [29]. If it does not meet the anticipated expectation, it is transformed into a backpropagation of the error, which returns the error along the original path and makes the error signal smaller by modifying the connection weights of the neurons in each layer. These forward and backward propagation alternate with each other and are seen as a "memory training" process. The system repeats these two processes until the error between the output value, and the expected value is reduced to within a specified range [30]. At this moment, the new samples are fed into the already trained network, and the corresponding output values are obtained.

The BP neural network model for hybrid teaching quality evaluation is established in the following steps.

4.1.1. Determination of the Number of Neurons in the Transmitter Layer. According to the evaluation indicator system of hybrid online and offline teaching quality, there are 19 subindicators in the system. These 19 subindicators can be used as the input neurons of the model. Therefore, the number of neurons in the input layer n is determined as $n = 19$.

4.1.2. Determination of the Number of Neurons in the Output Layer. This study uses the evaluation results as the output of the developed network and the number of output layers $m = 1$. The desired outcomes are grade A for excellent; grade B for good; grade C for pass; and grade D for fail.

4.1.3. Determination of the Number of Implied Layers of the Network. The indicated layer can be one or more layers. According to the theory of Kolmogorov, the following has been proved: for any given continuous function, a three-layer neural network can then accurately implement the predefined model functions. Therefore, in the hybrid online and offline teaching quality evaluation model, we choose the hidden layer as one layer.

4.1.4. Determination of the Number of Neurons in the Hidden Layer. In general, the number of neurons in the hidden layer is determined based on the convergence performance of the network. Too few neurons in the hidden layer may not train the network, or the obtained network may not be "strong" enough to recognize previously unseen samples, and the error tolerance is poor. However, too many neurons in the hidden layer may make the learning time too long, and the error may not be optimal either. Therefore, there is a problem with how to determine the appropriate number of neurons in the hidden layer of the network. Generally, the "trial-and-error method" can be used to compare the network output error with the desired error and select the simulation effect. The number of hidden layer nodes used for the best simulation results is chosen by comparing the fit between the output and desired errors, but this approach is tedious and time-consuming. The number of neurons in the hidden layer can also be determined by referring to some empirical formulas to determine. The following equations are two widely used empirical formulas.

$$s = \left(0.43mn + 0.12m^2 + 2.54n + 0.77m + 0.35\right)^{1/2} + 0.51, \tag{1}$$

$$s = (n + m)^{1/2} + a, \tag{2}$$

where a is a constant between 1 and 10, n is the number of neurons in the input layer, and m is the number of neurons in the output layer. In this paper, we initialize the number of neurons in the hidden layer based on the relevant empirical formula as $s = 12$.

4.1.5. Determination of Neuronal Transition Function. BP neural network neuron conversion function is generally chosen as sigmoid function:

$$f(x) = \frac{1}{\left(1 + e^{-\lambda x}\right)}, \tag{3}$$

in which the coefficient λ determines the degree of compression of the sigmoid function.

4.1.6. Determination of the Model Structure. From the above results, it can be determined that the structure of the hybrid online and offline teaching quality evaluation model based on the BP neural network is shown in Figure 1.

4.2. Model Training. A lecture called Introduction to Machine Learning in a university in Shanxi, China, is selected for a case study to demonstrate and validate the established model. We conducted a questionnaire survey among 60 students of this lecture. Surveyed subjects are asked to mark the 19 indicators from 0 to 9. The three-layer BP neural network shown in Figure 1 was used for identifying the above hybrid online and offline teaching quality assessment system. The numbers of neurons in the input layer, implicit layer, and output layer are 38, 12, and 1, respectively, and the learning rate $\eta = 0.85$. 40 randomly selected samples of data were considered as the training set of the neural network. The target error is 0.001. The specific training process is shown in Figure 2.

4.3. Model Test. After the training of the network was completed, it was tested using the remaining 20 sets of data. Then, the error between the evaluation target value and the actual evaluation target value output by the neural network is checked and compared, and the comparison results are shown in Table 4. It can be learnt that the output values of the hybrid online and offline teaching quality evaluation model built based on the BP neural network are very close to the real values. In other words, the model can accurately determine the teaching effectiveness based on each evaluation indicator.

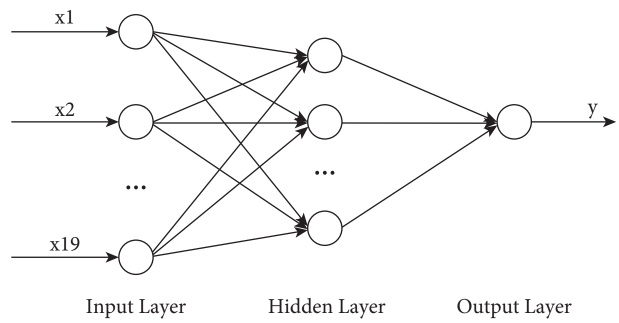

Figure 1: Structure of the BP neural network.

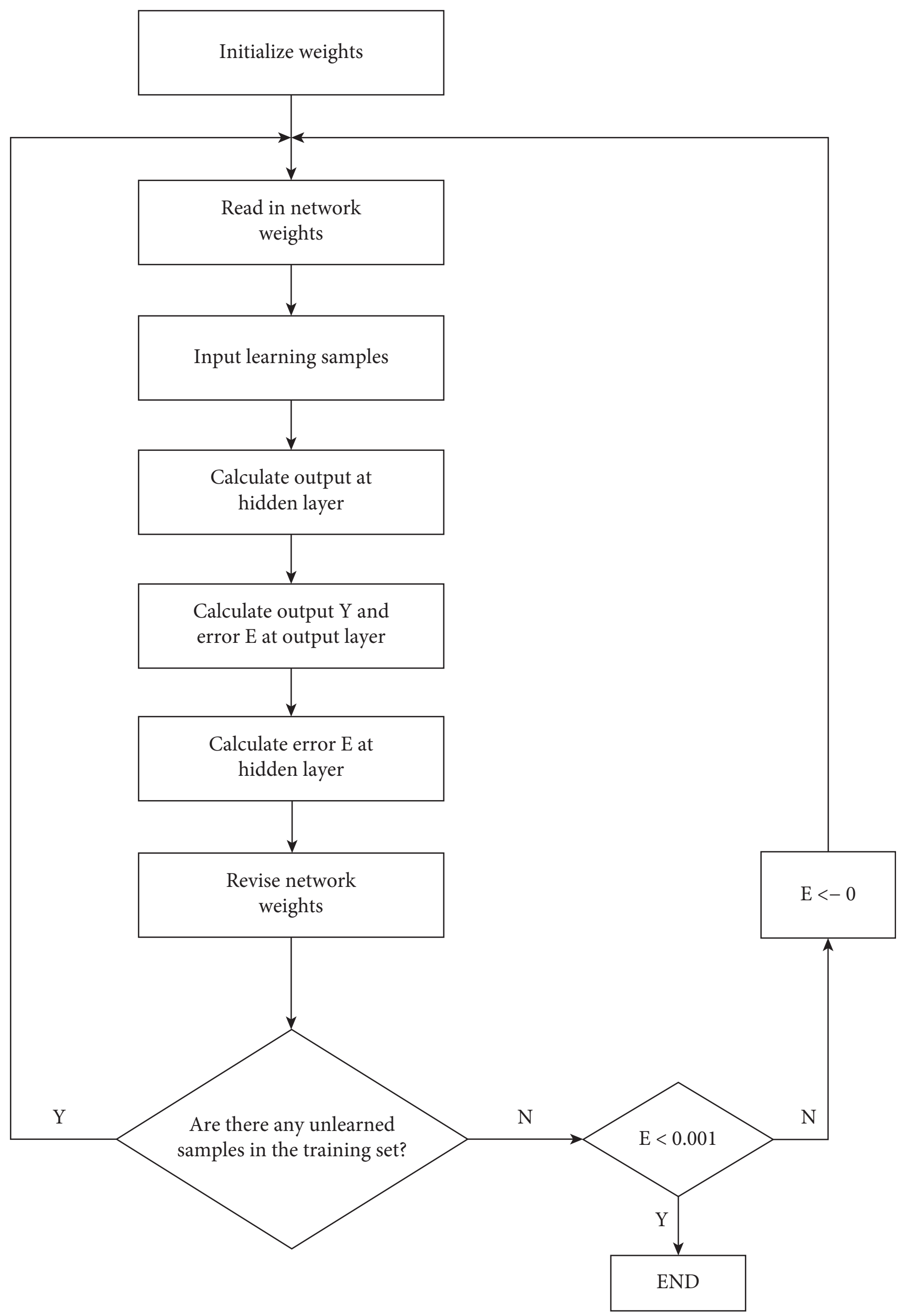

Figure 2: Process of model training.

Table 4: Results of model tests.

No	True value	Output from the model	Error (%)
1	6.89	7.01	1.74
2	6.46	7.01	8.51
3	5.75	5.79	0.70
4	6.24	6.66	6.73
5	8.48	9.03	6.49
6	9.12	8.94	1.97
7	8.25	8.22	0.36
8	7.77	7.2	7.34
9	6.48	6.99	7.87
10	6.99	6.99	0.00
11	8.48	8.55	0.83
12	7.98	7.99	0.13
13	8.02	7.95	0.87
14	8.23	8.01	2.67
15	6.73	6.52	3.12
16	5.77	5.61	2.77
17	6.97	6.83	2.01
18	9.03	9.11	0.89
19	9.24	9.99	8.12
20	7.35	7.74	5.31

5. Conclusions

The hybrid online and offline teaching quality evaluation system is a complex nonlinear system with many uncertainties between the input and output. The BP neural network model can effectively overcome the defects of traditional evaluation methods and weaken the human influence factors of index weight determination in traditional evaluation methods because of its highly nonlinear function mapping function and self-adaptive and self-learning ability. It is not only feasible but also has high accuracy. After the empirical study, we found that the error between the output value of the BP neural network model and the real value is relatively small. The performance can fully meet the requirements of practical applications. In addition, the output accuracy of the network depends on the number of input training samples, and the more the number of training samples, the closer the output teaching effect evaluation value is to the actual evaluation value. In conclusion, the developed hybrid online and offline teaching quality evaluation model established based on the BP neural network is expected to provide helpful reference for universities and teaching management departments to seek scientific solutions for teaching quality evaluation and improvements. This research still has two main limitations: (1) the evaluation model is still superficial; (2) only a case is applied to validate the model. In the future, the evaluation model can be further improved by introducing big data and deep learning. In addition, more cases should be used to further validate the developed indicator system and evaluation model.

Data Availability

The labeled datasets used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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Research Article

Sports Achievement Prediction and Influencing Factors Analysis Combined with Deep Learning Model

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Scientific sports training plans are only possible if you can accurately predict a player's performance. Accurate prediction of sporting performance not only is useful for athletes, but also helps to guide the development of sports. Research methods used in traditional forecasting include the time series method, analogy method, regression analysis, and other methods of analysis. Most of the data used to make these projections are derived from a relatively small set of static problems. A sports performance prediction model based on deep learning is proposed to address the current model's low prediction accuracy. Deep learning models are more accurate at predicting sports performance than traditional methods, and the difference between the two is greater in this study. Also, it performs well when it comes to both convergence and robustness.

1. Introduction

Sports performance prediction can help schools, sports teams, and sports training institutions develop scientific training methods that reflect the changing trends in sports performance [1]. Thus, athletes and coaches will be able to use these opinions as a basis for reforming physical education and training. The level of sports training is reflected in a person's ability to perform well in sports. In order to improve sports training and teaching, accurate prediction of sports achievement can be used to uncover the regular factors and characteristics of human training [2]. Because of this, the prediction of sports performance has always been a hot topic in the study of sports. There are many factors that influence a player's performance, and these factors interact and interact with each other in complex ways, making it difficult to predict a player's performance accurately using traditional methods [3]. At the same time, it is of great significance to study the prediction model of sports performance in promoting scientific training and improving sports performance [4].

Sports is the most attractive activity in modern society. As a special cultural phenomenon, its development has a profound and extensive influence on the development of sports culture, which in turn affects the development of other related cultures in society [5]. In light of the growing interest in sports development, this paper proposes a method for accurately predicting sports performance based on deep neural networks (DNN) [6–8]. Training and preparation goals are directly affected by accurate sports performance prediction, as well as the discovery of performance development rules. There is, however, a great deal of uncertainty in the data because of the small amount of data on which the current forecast is based, as well as the large randomness and hidden influence factors in the data generation process. Predicting sports performance is complicated because of the numerous variables involved (changes in human characteristics, age, various environmental factors, etc.). Sports performance prediction models are built using multivariate and multi-parameter statistical analysis. Statistics, information processing, and modern mathematics are among the topics covered in the course. Forecasting success hinges on selecting an appropriate and highly precise method. A sports performance prediction model based on DNN is proposed in order to improve the scientific guidance of sports training and predict sports performance.

The traditional method of predicting sports performance has some problems, such as high computational cost and poor adaptive anti-interference of parameters in the process of prediction, which leads to low prediction accuracy. Neural network (NN) is generally used in uncertain input-output function mapping, which can determine the linear correspondence. It has stable effectiveness and adaptability, forward propagation signal, and backward propagation error, and is often used in various fields [9]. It can accurately assess the athletes' physical quality level and make the key points and objectives of athletes' training content clear so as to have targeted and scientific training. Based on this, this paper puts forward a sports achievement prediction model based on deep learning. The quantitative evaluation system of special movement techniques has been established. This system can scientifically monitor and evaluate the development level of each athlete's athletic ability so that athletes can get scientific training. The performance test of the model proposed in this paper shows that the model improves the accuracy of sports performance prediction, and the prediction error can meet the requirements of practical application.

2. Related Work

Using a deep learning network, literature [10] predicts South Korea's daily comprehensive stock price index better than BPNN and case-based reasoning. Fernandez Molanes et al. [11] combines deep learning network and empirical mode decomposition to predict the error sequence of the initial prediction set and use this prediction value as a correction to correct the original prediction. In order to create a scientific, practical, and effective evaluation system for journals, literature [12] used DNN to build a dynamic evaluation model of journals. Neural network (NN) technology is employed in the literature [13] to model the project's value. It improves the back-propagation algorithm, which supervises and trains samples to obtain the weight factor, in order to determine the value of a project and help the decision-maker in project evaluation and decision-making. Biochemistry is a field where NN is used in the literature [14]. The biomolecular feature data matrix is obtained by extracting molecular features from biological structure analogs and selecting gene bonds and functional groups as discriminant factors. Multiple layers of NN structure have been proposed in the literature [15] as the basis for DNN architectures. Layer-by-layer training is typically used to abstract the data's unique characteristics before optimizing the network model as a whole. An artificial neural network (ANN) can be used to evaluate the total economic benefits of an enterprise, according to reference [16]. The economic indicators of enterprises are taken as the input of artificial NN, and the classification function of the network is used to classify enterprises. Literature [17] proposed a pattern integration operator based on the NN model. Compared with the mean operator, it is found that for multi-level time series, the prediction accuracy of the NN model can be greatly improved by using the pattern inheritance operator. Liu [18] proposed that the NN model has a three-layer NN structure. An input layer, hidden layer, and output layer. Each layer is connected with each other, and the connection weights are repeatedly learned and trained through error back-propagation until the corresponding weights can meet the requirements of the training mode. Literature [19] proposed that the DNN structure containing multiple hidden layers can be obtained through certain feature extraction and training methods. Literature [20] established a DNN prediction model based on the annual best performance data of the world women's heptathlon. Literature [21, 22] describes how to apply the NN method to the prediction in the field of market evaluation, enterprise evaluation, and economic management. The system block diagram of how to implement it in the language environment is given. The steepest gradient descent method is used to modify the weight and threshold. Literature [23, 24] pointed out that nonlinear sports models mainly include NN, grey model, Markov chain, and support vector machine. Literature [25] proposed that the combination of multi-population genetic algorithm and NN can consider the global optimization solution and local optimization solution at the same time. Literature [26] verified the prediction effect of a deep learning network on five financial time series data. The experimental results show that the prediction of mean square error and mean absolute error of deep learning network samples are better than back propagation neural network (BPNN). This paper establishes a sports performance prediction model by using the method of DNN and analyzes the reliability and error of the model. The test shows that the performance prediction model established by DNN can predict sports performance and evaluate the development level of physical quality more accurately than traditional prediction methods. This model can bring great convenience to the prediction of sports performance, and further improve the efficiency of modeling and the accuracy of prediction performance.

3. Methodology

3.1. Principles of Sports Performance Prediction. Changes in various natural conditions have an important impact on sports performance. The change of temperature, humidity, and atmospheric pressure will affect the change of ball speed. Natural conditions, such as the intensity of sunshine and the change of wind direction, will affect the individual achievements of players. This directly affects the players' technical level. Sports performance is related to many factors, and various factors interact with each other, which leads to very complicated changes in sports performance. The linear model assumes a periodical or rising trend of sports performance, which is inconsistent with the actual change characteristics of sports performance, and its application scope is limited [27]. Considering the influence of environment and weather on the accuracy of sports performance prediction, in the process of building the mathematical model of sports performance, according to fractional Fourier transform, a class of fractional generalized integrodifferential equations with distributed time delay is obtained, which represents the solution space model of sports performance prediction.

NN has the nature of biological NN type, and it can improve its own performance and understand the environment through learning. After the artificial NN is stimulated by the external environment, it can adjust the parameters of the NN to make the NN respond to the external environment in a new way [28]. DNN is mainly aimed at improving the shortcomings of traditional artificial NN. The artificial NN is prone to fall into local minimum and gradient disappearance when using gradient descent. The DNN divides training into two parts, namely, feature extraction and parameter optimization. Feature extraction is an unsupervised learning method, which can be completely based on unlabeled data, which is especially important for scenes with severe training data, and features and feature weights learned by automatic methods. Finally, the tagged data is used to fine-tune the parameters, which has achieved good results in the actual scene [29]. It truly reflects their inherent characteristics, thus overcoming the shortcomings of the multiple regression model and grey model. In this paper, the self-similar regression model of sports achievement is constructed, empirical mode decomposition and factor analysis are carried out on the time series of sports achievement, and the feature information clustering and information fusion processing of sports achievement are carried out by using the DNN classification model, so as to optimize the prediction model.

The number of nodes in the hidden layer is not only related to the number of nodes in the input and output layers but also related to the complexity of the problems to be solved, the types of transfer functions, and the characteristics of sample data. Suppose the collected sports scores form a sequence $\{y_1, y_2, \ldots, y_n\}$. Since the current sports score y_1 is related to its impact factor, there is a certain nonlinear relationship between them, namely,

$$y_i = f\left(x_{1,} x_{2,} \ldots, x_d\right), \quad (1)$$

where d is the embedding dimension of the input vector, which is selected by principal component analysis. F () is a nonlinear mapping function. The analysis of formula (1) shows that the fitting of the nonlinear mapping function f () is the key in the process of sports achievement modeling. Based on deep learning, this paper establishes a sports achievement prediction model. The workflow of deep learning for sports performance is shown in Figure 1.

The DNN model is extensible and can be optimized. The data in the sample library can be enriched by accumulating historical samples. The DNN's performance and prediction accuracy can be steadily improved over time by adding to and perfecting the expert sample data. Athletes' perceptions of the value of their sports training can be shaped by the public. By looking at the quality parameters of athletes who have achieved the expected value, a sports plan can be created. Improve the training plan's clarity and efficiency by adjusting the target parameters during the stage training effect test. Sports performance is modeled using the DNN model. In terms of chronology, previous sporting accomplishments are typical. The training set is used to train the combination kernel function correlation vector machine, and the adult prediction model of correlation vector scores based on the combination kernel function is established, and the test set is predicted to output the prediction results of sports scores based on the combination kernel function.

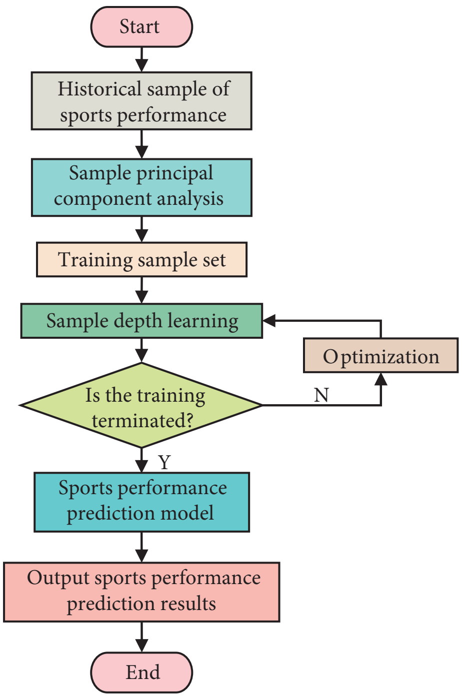

Figure 1: Deep learning workflow for sports performance.

3.2. Sports Performance Prediction Model Based on Deep Learning. The existing prediction models of athletes' special performance generally establish the functional relationship between special performance and quality training level through multiple regression methods and grey model and then predict athletes' special performance. The linear fitting feature space of sports performance is established, and the prediction model is constructed by the multiparameter constraint reconstruction method, which has a good prediction effect. To a certain extent, these prediction models reflect the relationship between special performance and training indicators and provide appropriate guidance for athletes' training [30]. However, these methods have some problems, such as high computational cost, poor adaptive anti-interference of parameters in the process of prediction, etc. And the determination of these models is based on certain assumptions. They need to set the mathematical expression of the special performance prediction model in advance. In fact, the functional relationship between special achievements and related factors is quite complicated, and the mathematical expression assumed in advance can't fit the relationship well. As a result, the prediction model of sports performance caused great errors and the prediction accuracy was low.

The establishment of the algorithm model of DNN requires seven steps: (1) Collection and grouping of sample data, (2) preprocess the data, (3) determining the number of hidden layers, (4) determining the number of hidden layer nodes, (5) training of DNN, (6) determining the initial weights of the network, and (7) testing the performance and generalization ability of the network algorithm model. Because of the huge amount of calculation, this algorithm requires high computer configuration, especially memory. Therefore, in the earlier period, many people advocated other algorithms to replace the problem of less network weights. However, with the rapid development of computer science and technology, there is no need for this concern, and the advantages of this algorithm are fully demonstrated. The training process consists of 10 modules, as shown in Figure 2.

Using the method of DNN, the nonlinear evaluation model of motor skill level, body shape, basic quality, and special quality is established, fitted, and predicted. Sports achievement data can be regarded as a set of nonlinear time series. The nonlinear time series method is used to analyze the trend of sports achievements, and the sports achievements are statistically analyzed. The fitting state model of using a multivariate statistical characteristic equation to describe sports performance is as follows:

$$\begin{pmatrix} X \\ P(X) \end{pmatrix} = \begin{Bmatrix} a_1, a_2, \ldots, a_m \\ p(a_1), p(a_2), \ldots p(a_m) \end{Bmatrix}. \tag{2}$$

In the formula $0 \le p(a_i) \le 1\,(i = 0, 1, 2, \ldots, m)$ and $\sum_{i=1}^{m} p(a_i) = 1$, representing the autoregressive statistical characteristic parameters.

Through the covariance matrix decomposition of the solution vector of the statistical equation, the principal component of the statistical characteristic information a_{ii} is obtained.

Research into the relationship between sports performance and body shape, function, basic quality, and special quality is extremely difficult in sports. This model is based on a functional relationship between sports performance and a variety of indexes of body shape, function, basic quality, and special quality. Regression based on logic can be thought of in the same way that neural networks are thought of in the same way that NNs are thought of. Because of its better parameter tuning and parallelization capabilities and higher feature magnitude than NN, logical regression is preferred over NN for large-scale feature estimation and analysis. Logic regression is a linear model, while DNN is a non-linear model, so it is necessary to double process features in order to get the best results.

(1) A non-zero random number is set whose V_{kl} is small, and the setting range is the weight coefficient of each layer.

(2) $A = (a_1, a_2, \ldots, a_m)$ is the input sample, and $E = (e_1, e_2, \ldots, e_m)$ is the corresponding expected output.

(3) The output of the k$^{\text{th}}$ neuron is located in the h layer, as shown in formula (3).

$$\begin{aligned} G_k^h &= \sum V_{kl} A_k^{h-1}, \\ A_k^h &= s\left(G_k^h\right). \end{aligned} \tag{3}$$

Usually, formula (3) will be expressed as a sigmoid function:

$$s(a) = \frac{1}{(1 - \exp(-a))}. \tag{4}$$

(4) Evaluate the learning error d of each layer, and $h = n$ in the output layer:

$$f_k^n = A_k^n \left(1 - A_k^n\right)\left(A_k^n - E_k^n\right). \tag{5}$$

The remaining layers, there are

$$f_k^h = A_k^h \left(1 - A_l^h\right) \sum V_k f_k^{h+1}. \tag{6}$$

(5) Modify the weight coefficient V_{kl}:

$$V_{kl}(p + 1) = V_{kl} - q \cdot f_k^h \cdot A_l^{h-1}. \tag{7}$$

(6) Judge whether the calculated weight coefficient of each layer can meet the requirements. If it can meet the requirements, the calculation can be finished; otherwise, the process has to be repeated from step (3).

On the basis of the statistical analysis model of sports achievement, a prediction model of sports achievement is established by using DNN. Empirical mode decomposition and factor analysis are carried out on the time series of sports achievements in DNN. The logical regression is better for discrete features. Therefore, it is necessary to discretize the normalized features. There are many ways to discretize features. Usually, continuous features are mapped to fixed values. Generally, the feature value domain is equally divided into fixed intervals, and the intensity of each interval can be customized.

Sports performance prediction can help schools, sports teams, and sports training institutions develop scientific training methods that reflect the changing trends in sports performance. We can monitor the progress of athletes' physical fitness and sports performance during training, comparing the results to theoretical expectations and making adjustments to the training plan as needed, thus keeping the entire training process in check. One of the most important features of the NN is its ability to learn on its own, as well as its ability to generalize. This paper's deep learning model outperforms both the multiple regression model and the grey model in terms of performance. The mathematical expression of an athlete's unique performance prediction model does not need to be determined in advance. Fitting and prediction accuracy can be improved by more objectively mapping the correlation between athletes' quality training levels and their performance.

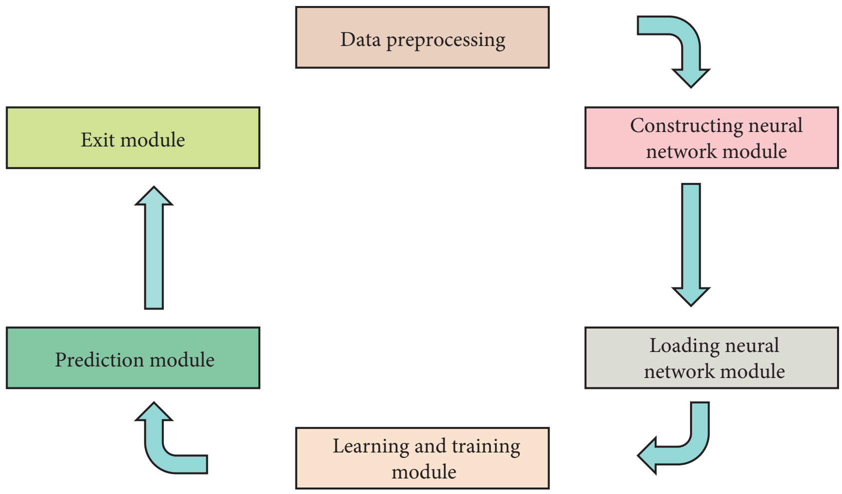

Figure 2: Training prediction process.

4. Result Analysis and Discussion

The problem of performance prediction is characterized by the strong randomness of data, many influencing factors, complex interaction and relationships among factors, etc. Therefore, the research results of sports performance prediction obtained by traditional prediction research methods are not ideal. Through sports, survival of the fittest and ranking, we can test the technical level of sports, select talents, motivate backward players, and attract more people to participate in sports.

A large amount of measured data needs to be filtered and filtered in order to conform to a sample set of effective patterns. Sample libraries can be built up over time as more historical data is accrued, allowing the model's inputs and outputs to be filtered based on the reality of a given situation, as well as the results from statistical calculations. The principal component analysis (PCA) is performed on these variables because there are some recurring relationships between athletic performance and things like height, weight, vital capacity, 50-meter running, sitting and bending forward, 800-meter running, and one-minute sit-ups. Figure 3 depicts the time domain waveform description of the sample data as described by the simulation settings and used to design the sports performance prediction model.

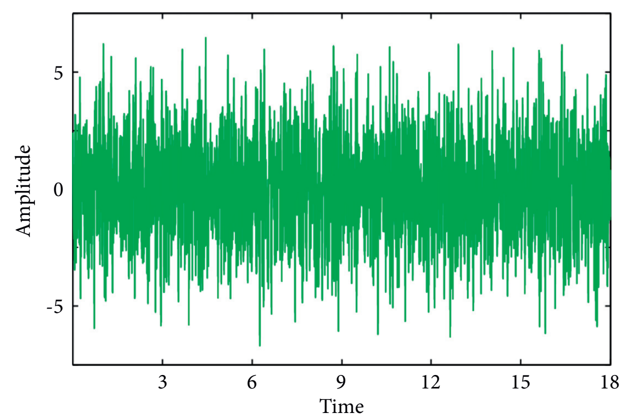

Figure 3: Time-domain waveform of sports performance statistics.

After many training and prediction tests, it is found that the addition of some test data will affect the convergence speed and prediction accuracy of the model. For example, athletes with insufficient training years or athletes whose test results in deviation of some indexes due to some special conditions. Therefore, this kind of data is excluded. Taking the collected statistical samples of sports performance as the test set, the simulation analysis of the sports performance prediction model is carried out, and the comparison results of prediction errors of different methods are shown in Figure 4.

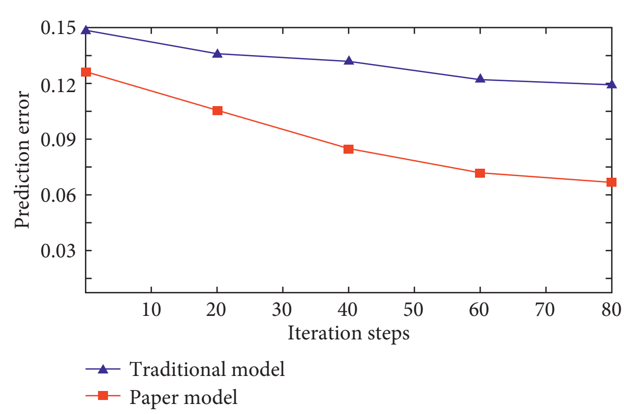

Figure 4: Forecast error analysis.

Each node in a DNN's input layer is defined as a feature, and nodes in the same layer are mutually independent. Features must be normalized before they can be compared in logistic regression or deep neural networks (DNN). The model jitter will not deviate when the normalized features are trained in the model, and the weights of the features will be more stable. In order to make predictions about an athlete's special performance, models that use multiple regression and a grey model establish a functional relationship between special performance and quality training level. The statistical distribution of unified samples and the unification of basic measurement units can be achieved by normalization. The trend of deep learning neural training in this paper is shown in Figure 5.

More samples in the input layer mean more computation, more hardware requirements, and longer time consumption when using a DNN to train samples repeatedly. That's why cutting down on the number of training indicators is essential. For calculating the correlation coefficient and figuring out the degree of correlation between each index and the level of movement technology, we use the correlation analysis method. Multiple indicators with significant and conclusive impact on the level of motor skill have been eliminated using cluster analysis. Pictured in Figure 6 is a curve that shows the relationship between expected and actual deep learning outcomes. It can be seen in Figure 6 that the predicted long jump value and the actual long jump value are very close. A great deal of research has led to excellent standing long jump results. There was a significant improvement in prediction accuracy with the prediction model.

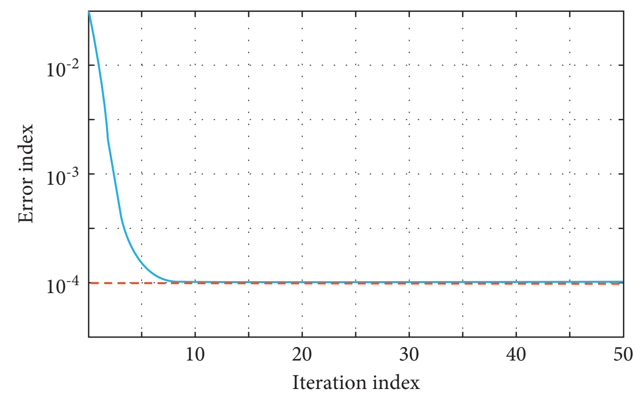

Figure 5: Trends in DNN training.

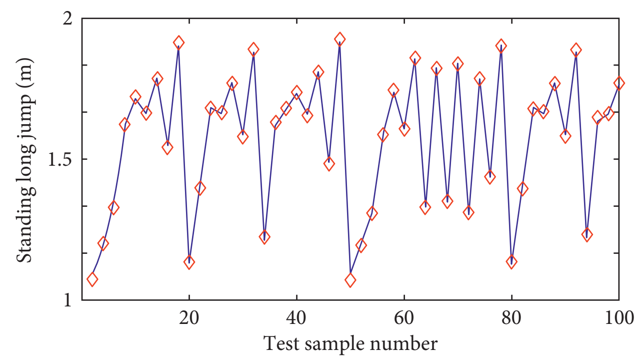

Figure 6: Fitting curve of predicted value and actual value of deep learning.

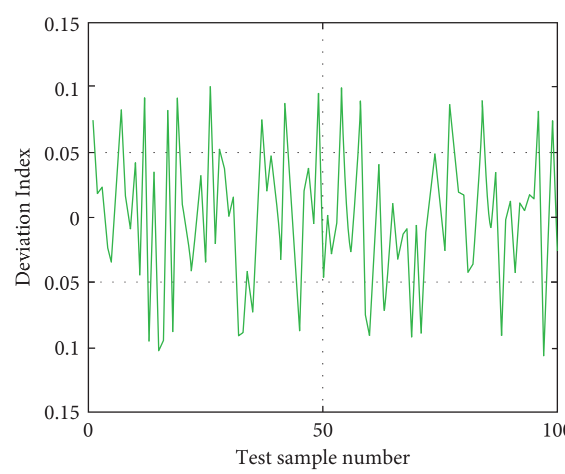

Figure 7: The prediction deviation curve of deep learning.

Filter and screen a large number of measurement data to make them conform to the sample set for establishing effective patterns. Because there are some rules and relationships between the input and output of the model, which data should be retained and filtered are mainly determined by the actual situation, experience, and statistical calculation results. This sample library can be gradually supplemented and improved with the increase of historical data. The model has a small error range and high prediction accuracy for athletes' performance, which shows that the model is accurate and effective. In some practical problems, no standard function model or function analytic model is highly nonlinear, so we can use DNN to predict the approximate value. The change curve of prediction deviation of deep learning is shown in Figure 7. It can be seen in Figure 7 that the deviation between the predicted value and the actual value of sports performance is relatively small. And the variation amplitude of the prediction deviation is also small. The results show that it is feasible and effective to introduce the deep learning model into the standing long jump performance prediction.

Sports achievement is an important manifestation of sports training levels. Through the accurate prediction of sports performance, we can dig out the regular factors and characteristics of human training, thus promoting the improvement of sports training and sports teaching. Sports have a special activity flow, clear purpose, distinctive competitive features, and a complete set of competition rules and methods. At the same time, it is of great significance to study the prediction model of sports performance to promote scientific training and improve sports performance. As a new algorithm in current machine learning, the DNN is excellent in model representation and data processing ability. The DNN can produce better results in data representation through complex network structure and deep network layers. Using the hierarchical structure of the DNN can realize the nonlinear intersection of features. Compared with the simple combination intersection of discrete features, the DNN can learn features more fully and accurately. This model shows the mapping relationship between athletes' performance and various factors. And the convenience and accuracy of sports performance prediction are realized. Furthermore, it improves the efficiency of modeling and the accuracy of performance prediction.

5. Conclusions

People today place a high value on participating in sports. A lot of time and money was also invested in the collection of sports performance data. For the future direction of sports teaching, it is important to analyze historical sports achievement data and predict future sports achievement. There is a synergistic relationship between scientific research and the project's development. For coaches on the front lines, a lack of theoretical research will inevitably stifle the development of movement technology. Sports performance and related factors must be studied quantitatively, using interdisciplinary approaches, as soon as possible. The multivariate and multiparameter statistical analysis is used to build a model for sports achievement prediction. Statistics, information processing, and modern mathematics are among the topics covered in the course. In this paper, a sports performance prediction model based on deep learning is developed using the nonlinear modeling advantage of NN, and the model's performance is thoroughly tested and analyzed through several prediction examples. Using this model, the sports performance prediction accuracy has increased and the prediction error has decreased, compared to traditional methods. The model can be used in a real-world setting.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Enterprise Financial Influencing Factors and Early Warning Based on Decision Tree Model

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The development of a financial analysis system is essential for modern businesses to improve their management systems. In light of the global financial crisis, it is even more critical for businesses to develop a rigorous financial analysis system to avoid risks. DM does not necessitate the development of a complex mathematical theory; as long as data are filtered, hidden features between data can be found. The decision tree algorithm is one of several DM methods. With the rapid advancement of DM technology, theories and applications related to it are maturing at a rapid pace. This study will develop a decision tree-based enterprise financial risk analysis and early warning model, analyze enterprise financial influencing factors, apply the decision tree method to enterprise financial risk analysis and early warning, and provide a reference for enterprise financial risk early warning and risk control decision-making.

1. Introduction

Many scholars studying enterprise management focus on how to make businesses succeed, but pay less attention to how to keep businesses from failing [1]. However, a large number of enterprise management case studies show that due to the uncertainty of the objective environment and people's limited ability to understand it, as well as poor internal management of the enterprise, it may lead to an enterprise crisis, but the enterprise has no forewarning of the crisis, and no preventive measures, resulting in enterprise management failure [2]. A financial analysis system is a real-time monitoring system for potential risks in business management activities based on enterprise informatization [3]. The construction of a financial analysis system is of great practical significance to improve the management system of modern enterprises. Especially under the background of global financial crisis, the establishment of a scientific financial analysis system is more important for enterprises to prevent risks [4]. Enterprise financial management involves many and complicated work contents, which requires financial managers to plan and deploy enterprise financial management contents reasonably based on the development of market economy, so as to ensure the smooth progress of enterprise financial management activities. Therefore, how to find and correctly predict financial crisis as soon as possible is of great practical significance for reducing enterprise operation risk, protecting the interests of investors and creditors, supervising listed companies by government departments, and preventing financial crisis [5]. If an enterprise can establish an effective financial analysis system, it can find and take effective measures to avoid greater losses when the enterprise's financial situation is just in crisis, so that the enterprise can remain invincible in the fierce market competition [6].

Data mining (DM) does not require complex mathematical theoretical derivation. As long as data filtering is used, the hidden characteristics between data can be found [7]. A decision tree is a case-based induction system that can generate decision tree representation classification rules from a set of unorganized and irregular examples [8, 9]. Traditional statistical models include multivariate discriminant analysis model and logarithmic regression model [10]. Statistical models have obvious interpretability, but they often require data to obey assumptions such as multivariate normal distribution, and their stability is not high [11]. Financial risk exposure is often the last stage of overall risk exposure; that is, all potential problems begin to appear and are exposed in the form of financial risk [11, 12]. This study will establish the enterprise financial risk analysis and financial crisis early warning model based on the decision tree algorithm, analyze the enterprise financial influencing factors, apply the DM method to the enterprise financial risk analysis and crisis early warning, and provide reference for the enterprise financial risk crisis warning and risk control decision-making.

With the development of IT, some classification and prediction algorithms of AI and machine learning have also been introduced into the field of financial credit risk assessment, mainly including the methods of an artificial neural network [13, 14] and decision tree [15]. The fault tolerance, flexibility, and generalization functions of an artificial neural network are all excellent. However, neural network modeling is a difficult approach to master; training a model takes a long time and thousands of iterations, and it also needs human troubleshooting [16]. The traditional financial management strategy is no longer applicable to the current enterprise financial management. It can be said that seeking an innovative and forward-looking financial management strategy has become an urgent problem to be solved in the current enterprise financial management [17]. Decision tree is a top-down classification method. It constructs a decision-making knowledge representation by learning a group of training samples [18]. According to the essential requirements of the theoretical connotation of enterprise financial early warning mechanism, taking the theoretical scientificity and practical operability as the basic requirements, this study starts from two aspects of short-term early warning and long-term early warning, and uses the early warning analysis methods of qualitative, quantitative, and qualitative and quantitative to establish an early warning system that can effectively predict enterprise financial crisis. Compared with a neural network, decision tree is easier to understand. Decision tree has the advantages of low requirements for data preparation, allowing the existence of outliers, high speed, high precision, and simple generation mode.

2. Related Work

Literature [19] proposes that the establishment of a decision tree can be completed as long as the database is scanned several times, which also means that less computing resources are required, and the situation containing many predictive variables can be easily handled. Literature [20] employs a linear probability model to examine the banking industry's early warning system for financial crises. A linear probability model is a subset of a multivariate analytic model that may be used to evaluate the likelihood of a company failing. According to literature studies [21, 22], the financial crisis early warning model must be adjusted in accordance with the production and operation status as well as the financial status of enterprises, in order to ensure that the discrimination rules of the early warning model are suitable for the current market environment, given the continuous development of computer technology and AI and the increasing necessity of enterprises to deal with the changeable market competition environment. Literature [23] questioned the traditional way of using all available financial ratios to predict enterprise crisis based on the correlation between some financial ratios and the lack of distinction between the importance of each ratio. Literature [24] first used discriminant analysis to extract 5 financial indicators with prediction ability from 22 financial indicators and conduct modeling analysis. The decision tree algorithm has a greater accuracy for financial crisis early warning than the Z-score scoring model, according to literature [25]. Literature [26] uses nine independent variables and finds at least four types of variables that significantly affect the company's bankruptcy probability: company size, asset structure, company performance, and current asset liquidity, which are put into the model.

Most of the financial early warning indicators put forward in the above research are common financial evaluation indicators. Financial evaluation indicators cannot sensitively and timely reflect the risk degree of enterprise financial situation, and they do not correspond the financial risk analysis with early warning indicators one by one, so as to accurately diagnose the hidden dangers of enterprise financial crisis. Based on the theory of enterprise early warning management and macro-economic early warning methods, this study analyzes the financial warning sources that lead to enterprise failure and the financial influencing factors that identify enterprise crisis, and builds a financial early warning model based on the decision tree algorithm.

3. Methodology

Cash is the blood of the enterprise, the primary factor restricting the business activities of the enterprise, and the focus of attention of operators, investors, and creditors [27]. The bankruptcy of many enterprises is caused by insufficient cash flow and inability to repay debts when due. The analysis basis of cash flow early warning is the cash flow statement of various industries and enterprises. If the cash flow exceeds the needs and there is surplus cash, it has strong adaptability. Income quality mainly analyzes the proportional relationship between accounting income and net cash flow [28]. The operating ability index is an index to measure the efficiency of an enterprise in using its resources, which reflects the enterprise's ability to manage assets [29]. If the operating ability is poor, it may indicate the possibility of financial crisis in the future.

The definition of the information entropy can be described as follows:

$$\text{Entropy}(s) = \sum_{i=1}^{n} -p_i \log_2 p_i. \tag{1}$$

Here, p_i is the proportion of S belonging to category I, S represents the sample set, and n represents the number of target attributes.

We can define the information gain as follows:

$$\text{gain}(S, A) = \text{entropy}(S) - \sum_{v \in \text{Value}(A)} \frac{|S_v|}{|S|} \text{entropy}(S_v). \tag{2}$$

Among them, Value (A) is the value set of attribute A, v is a value in Value (A), $|S_v|$ is the number of samples whose attribute A takes the value of mouth, and $|S|$ is the total number of samples.

We can define the information entropy as follows:

$$\begin{gathered} \text{gain ratio}(S, A) = \frac{\text{gain}(S, A)}{\text{SI}}, \\ \text{SI} = -\sum_{i=1}^{n} \frac{|S_i|}{|S|} \log_2 \frac{|S_i|}{|S|}. \end{gathered} \tag{3}$$

Among them, S_1 to S_n are a set of n samples formed by dividing S with n-valued attributes.

We can define the normal gain as follows:

$$NG = \frac{\text{gain}(S, A)}{\log_2 n}. \tag{4}$$

It is shown that the information gain standard tends to prefer finer division, whereas the information gain rate prefers uneven division, and the normal gain is more effective than the former two.

In order to ensure the innovation effect of enterprise financial management, enterprise managers should give priority to building a good corporate financial culture atmosphere and provide a good guarantee for the smooth progress of various financial management activities of enterprises. In the process of practice, it is suggested that the internal publicity and management of enterprises should focus on the importance of financial innovation, so that all employees can form a good sense of enterprise financial management [30]. It is best to integrate humanistic ideas into the process of creating financial innovation culture to ensure the formation of a harmonious atmosphere of corporate culture. To change the traditional concept of enterprise financial management, first of all, it is necessary to make the enterprise management pay attention to and accept the brand-new financial management system, and have its own system to change the concept of enterprise financial management. The adoption of brand-new management concepts by management in enterprise management can effectively promote the pace of reform and innovation of financial management concepts, and fully implement the reform and innovation of enterprise financial management concepts.

Usually, the cash flow of business activities should be positive, the cash flow of investment activities should be negative, and the cash flow of financing activities should be positive and negative. However, as a whole, cash can flow between operation, investment, and fund-raising activities, and it is not possible to judge whether an enterprise is safe and its security degree only by the flow level of a certain activity, the positive and negative ratio among various activities. Figure 1 shows the structure of an intrusion detection system for the enterprise financial system.

The first year or previous year's data of an enterprise should not be taken as a critical point of the enterprise's security or crisis, so financial ratios such as the growth rate of the enterprise's net operating cash flow calculated from this can only reflect the fluctuation of the enterprise's cash flow, not the security or crisis degree of the enterprise. Cash flow is what an organization can really use to pay off its debts, and a comparison of cash flow and debts can better reflect its solvency. The cash flow ratio and total cash liabilities ratio are two financial early warning indicators that reflect liquidity. The cash flow ratio is the most detailed financial ratio for evaluating an organization's short-term solvency. It corrects the flaw in traditional ratio analysis that is the current ratio index, and it can dynamically and historically monitor a company's short-term solvency. According to the premise of the decision tree algorithm, financial early warning necessitates index selection, training, and testing. The specific design concept is depicted in Figure 2.

Solvency refers to the ability of an enterprise to repay debts due, and the income obtained by the enterprise in the current period should first repay various debts. The indicators of solvency include the repayment ratio of principal and interest of due debts, the ratio of operating net cash flow, the guarantee multiple of cash interest, and so on. The analysis indexes of enterprise's ability to pay mainly include the net cash flow of common stock per share operating activities, the net operating cash flow of paying cash dividends, the financing ratio of investment activities, and the cash reinvestment ratio. However, these indicators are not in line with the definition of enterprise's ability to pay. The income earned by enterprises should be used to repay debts first and then used to meet various expenses. The enterprise financial crisis early warning theory is a broad concept that spans several fields. It is a knowledge that covers many disciplines, such as enterprise risk management, project investment management, dynamic information technology, and mathematical modeling. The research of enterprise financial crisis early warning is to mine rules with high trust according to the fluctuation of financial indicators. When the fluctuation of indicators exceeds a certain range, the system should give an early warning.

If $x_i \in R^n$ is the factor influencing the financial risk forecast, y_i is the financial risk forecast value. The financial risk prediction model based on the decision tree algorithm is to find out the relationship between x_i and y_i, which is given as follows:

$$\begin{gathered} f\colon R^n \longrightarrow R, \\ y_i = f(x_i), \end{gathered} \tag{5}$$

where R^n is the factor that affects the financial risk forecast. According to the decision tree algorithm, establish the financial risk prediction model as follows:

$$f(x) = \sum_{i=1}^{k} (a_i - a_i^*) K(x, x_i) + b, \tag{6}$$

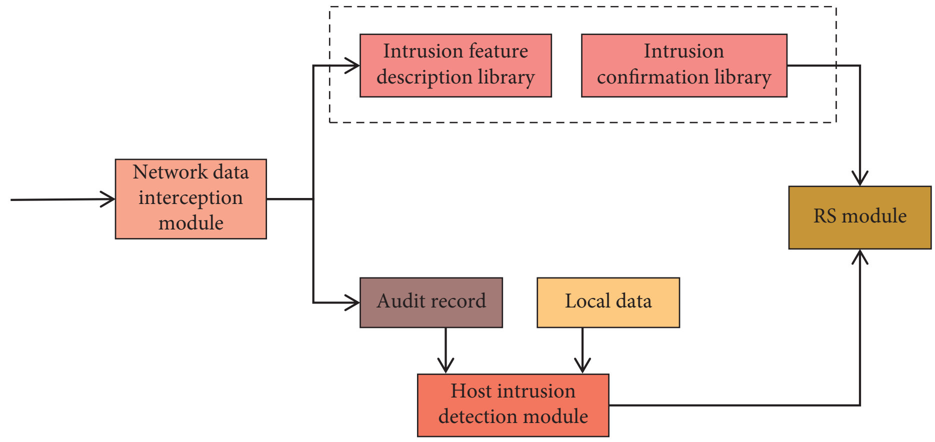

FIGURE 1: The construction of an intrusion detection system for an enterprise finance system.

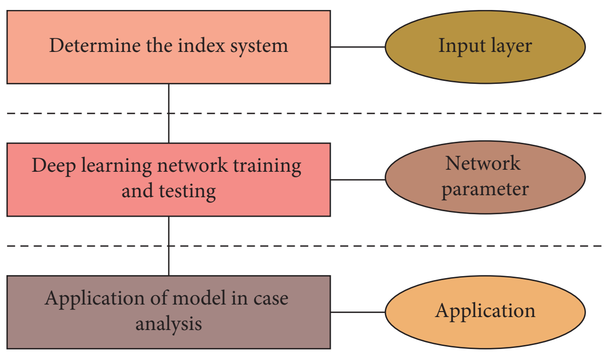

FIGURE 2: Design idea of a financial early warning model.

where x is the factor that affects financial risk and x_i is the i sample in the k sample. $K(x, x_i)$ is the kernel function, which is given as follows:

$$K(x, y) = \exp\left|-\frac{\|x - y\|^2}{2\sigma^2}\right|. \tag{7}$$

In the case of insufficient assets, entrepreneurs must borrow or finance a large amount, so they must mortgage most of the income obtained when the project is successful. When an enterprise lacks solvency, it will result in insufficient funds, delayed payment of interest, and principal to creditors, which will easily lead to financial crisis and bankruptcy. In financial early warning, the ratio of long-term debt to working capital and asset-liability ratio are mainly used. The asset-liability ratio is the core index of long-term financial early warning, which reflects how much of the total assets are raised by borrowing and reflects the long-term solvency of enterprises. When the rate of return on investment is greater than the loan interest rate, the more loans, the more profits, and the greater the financial risk.

4. Result Analysis and Discussion

Enterprises cannot grow without the support of funds, which are required for their operations. Enterprise fund management is a critical component of enterprise financial management, as it introduces risks to enterprise internal management, such as capital, management, and business risks. Enterprise financial management objectives evolve and change in response to changes in the market economy environment of their industries, and financial management objectives evolve and change in response to changes in the market economy and social consciousness. As a fundamental assurance to enable the seamless implementation of business financial innovation management, financial innovation culture may have a direct influence on enterprise financial management level to some extent.

The risk assessment of this study will start from qualitative and quantitative aspects, and qualitative assessment, such as expert consultation and scenario analysis, will be used for moral hazard judgment. Regarding the cash flow of enterprises, the financing amount will be determined quantitatively, such as the decision tree algorithm. Most of the current risk management is limited to compliance and internal control. Most of the operating funds of enterprises come from financing channels, and most enterprises belong to family nature, which is influenced by the family factors of initial enterprise financing. Family management is also the obstacle of enterprise fund management, and most financial management problems appear here. Because there is no professional management of funds, the management effect of enterprises is not good. Because most of the funds raised by enterprises are bank credit, the low reputation of enterprises will lead to difficulties in bank loans, which will have an impact on enterprise financing. If enterprises lack funds for development, it will lead to difficulties in capital turnover and hinder the progress of enterprises. Figure 3 depicts the link between enterprise size and cost.

As a matter of fact, the enterprises themselves lack awareness of innovative ideas, which leads to the lack of awareness of innovative ideas of financial management among enterprise financial managers. In the long run, the financial management of enterprises is difficult to reach the expected level and even lags behind. The basic function of enterprise financing is to enable enterprises to obtain certain capital for further development and expansion with the lowest risk, and this kind of financing method belongs to the basic financial financing method. However, as the economic

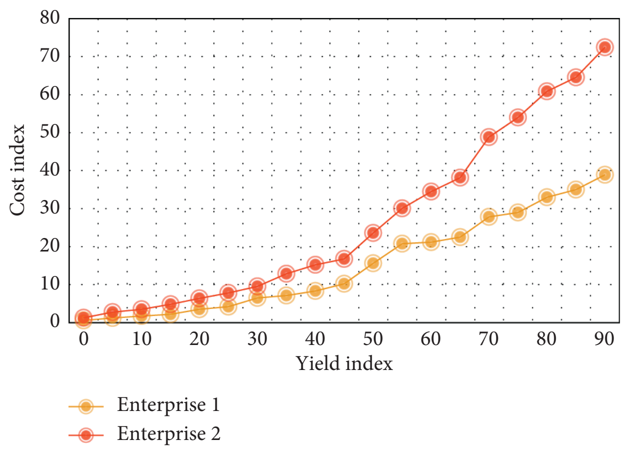

Figure 3: The cost-benefit analysis of the link between business size and cost.

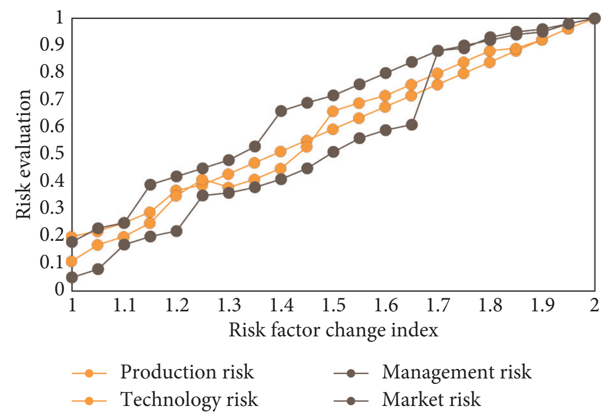

Figure 4: Evaluation and change of risk factors.

system develops and changes, the concept of knowledge economy gradually gains a dominant position in the composition of enterprise assets, and enterprises will include knowledge capital in financing, laying a solid foundation for knowledge capital to become the core capital of enterprises and, as a result, knowledge capital will gradually become an important core capital for enterprises to survive. Internal control is a key component of enterprise financial management, as it ensures the legality of financial actions, the real effectiveness of financial information, and the integrity of firm assets.

Enterprise financial management evaluation is an important link in enterprise financial management, and it is also the best way to test enterprise financial management ability and innovation ability, which can effectively help enterprise financial management to find out shortcomings, thus contributing to the reform and innovation of enterprise financial management. Moreover, the construction of enterprise financial management evaluation mechanism mainly depends on the economic added value of enterprises, the amount of circulating capital, and the market demand in the industry. The evaluation is only aimed at the capital value targets of enterprises, and isomorphic and effective evaluation methods are used to find out the development process of innovation mechanism of each unit in enterprise management.

The major purpose of business financial early warning is risk control, which includes not only anticipating financial hazards but also identifying the reasons that contribute to financial difficulties in a timely manner. Figure 4 depicts the evaluation and modification of risk variables.

The analysis shows that the business is sensitive to business risks and less sensitive to financial risks. The financial management system lacks the support of an innovative theory, and it is generally difficult to provide internal driving force for the deepening development of enterprise financial management. In addition, appropriate combination or introduction of modern financial management technology can provide guarantee for the sound development of the enterprise financial management system. However, some enterprises lack this awareness, so they lack soundness in the construction of the financial management system. The improvement of enterprise management ability comes from all directions, and with the popularization and development of new enterprise management concepts and methods in the current era, the overall management level of enterprises in all aspects is constantly improving, and as the core of enterprise management, the enterprise financial department should constantly study and improve the enterprise financial management ability. For example, the importance of implementing innovative financial management should be made clear, and the inefficiency of financial management in the past should be avoided. When necessary, relevant innovation management training activities can be held regularly, so that financial personnel can know the shortcomings of their own management consciousness in time. In practice, it is suggested that financial personnel should actively improve specific problems, avoid previous management risks, and ensure that the overall financial management effect of enterprises can achieve the expected results.

Compare the indexes at the same level and provide a proportionate scale score based on the indexes' relative relevance. Figures 5 and 6 depict the data link between weight and assessment value.

In view of the lack of innovative awareness of financial management in enterprises at present, it is suggested that enterprise leaders should deepen their awareness of financial management in enterprises from multiple working levels, so that all employees in service can clearly understand the importance of innovative financial management. Focus on the integration and strengthening of enterprise financial management activities, and try to infiltrate financial innovation management into all management links. With the continuous development of China's market economy, the competition among enterprises is becoming more and more fierce, and the financial management department has gradually played a greater role in the management of enterprises. However, with the development trend of modern enterprises, enterprises have put forward higher requirements for the ability and professionalism of the staff of the financial management department, and enterprises need to regularly carry out knowledge learning and skills training for

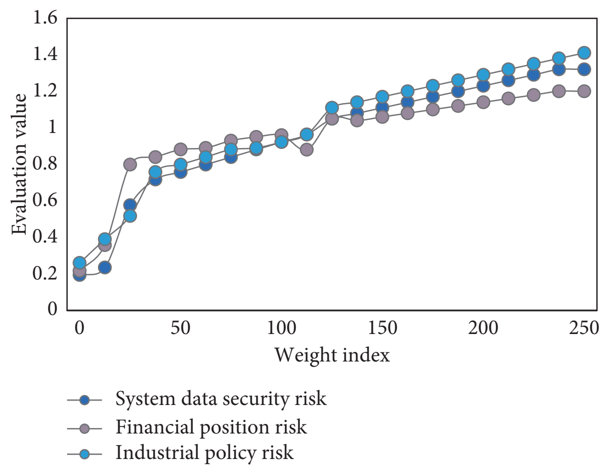

Figure 5: The weight of financial risk and the value of evaluation.

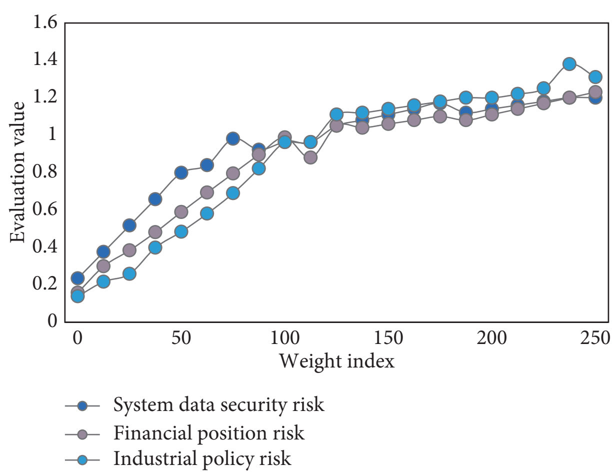

Figure 6: Financial risk weight and evaluation value.

the staff of the financial management department, so as to improve the standards of financial management.

Modern enterprise management believes that the implementation of enterprise financial innovation culture is the prerequisite to effectively promote the scientific implementation of various business management activities of enterprises, and it must be implemented and implemented with emphasis. The indispensable part of the financial management system innovation is the support of the financial management system. In reality, there is a big difference between enterprise financial management innovation and financial management system, which makes them unable to form a mutually promoting relationship. However, the lag of the financial management system leads to that the financial management system cannot provide institutional support for financial management innovation. As promoters of various financial management activities, it is necessary for financial personnel to shoulder their own heavy responsibilities, make clear the importance of implementing innovative financial management, and avoid the inefficiency of financial management in the past. In this study, Figure 7 shows a performance comparison of the decision tree approach with the conventional technique.

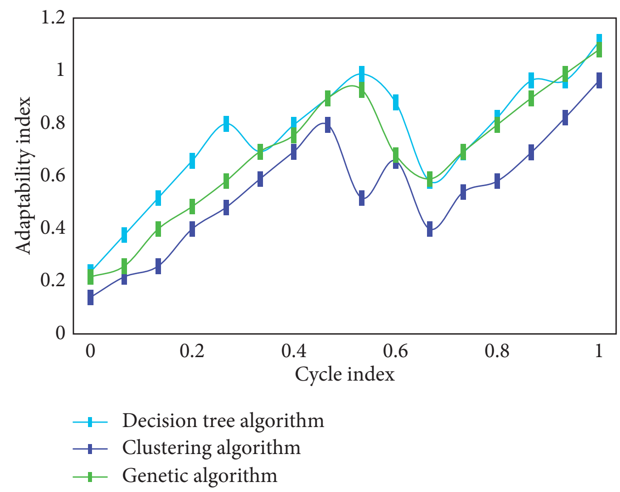

Figure 7: Algorithm performance comparison.

The financial department of an enterprise not only meets the development needs of the enterprise, but also improves the market competitiveness of the staff of the financial department through continuous training and study of professional ability, and provides new impetus for the reform and innovation of the financial management ability of the enterprise, thus realizing the dynamic innovation of the financial management of the enterprise. In practice, it is suggested that enterprise managers should give priority to improving the content of the financial management system to solve the problem of insufficient internal driving force of financial management in the past. At the same time, combining with IT, the related management platform system is built to reduce the delayed effect of financial information management.

As illustrated in Figure 8, the decision tree algorithm model is used to the risk prediction of sample data, and the prediction results are mostly consistent with expert recommendations.

In practice, each assessment index is divided into three zones: safety, early warning, and crisis, with critical values for each zone specified. The actual value is compared with the critical value to determine the region where the early warning index is located, so as to judge the degree of risk faced by the enterprise. Single variable model analysis is relatively simple, but it cannot comprehensively explain the overall financial situation of the company. With the knowledge capital gradually becoming the dominant factor in the capital structure of enterprises, it is necessary to add the ratio of knowledge capital to the distribution of enterprise wealth, and by confirming the status of knowledge capital, people with certain knowledge capital can enter the distribution of enterprise wealth through their own knowledge capital and get due remuneration. In addition, the wealth distribution system, which is used to distribute employees' salaries according to the assessment mechanism such as working hours and work quantity, has been effectively reformed and innovated, thus transforming into the way of salary distribution based on the value created by individuals for enterprises.

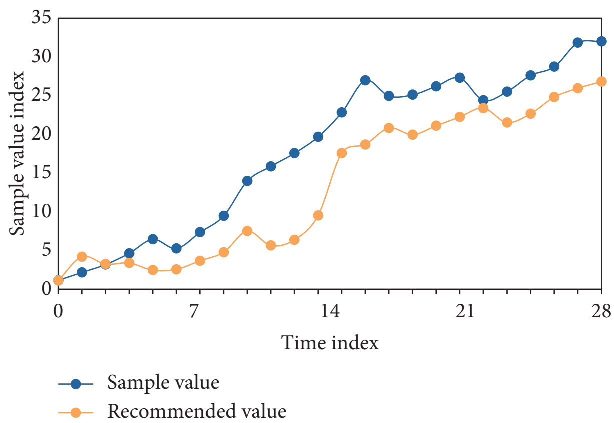

Figure 8: Comparison of recommended values and evaluation values.

5. Conclusions

With China's enterprise bankruptcy and stock market exit mechanisms improving all the time, most businesses have realized the importance of putting in place a financial presubstitution system, and their risk awareness is increasing. Traditional statistical techniques require a lot of assumptions, so they cannot handle a lot of data and are often limited to financial data. This research will use the decision tree algorithm to develop an enterprise financial risk analysis and financial crisis early warning model, assess enterprise financial influencing factors, and apply the DM technique to enterprise financial risk analysis and crisis early warning. If a warning is found in this month's operation, you should check the detailed indicators to determine the causes and departments of the problems, and take appropriate measures to solve and effectively control the problems.

Compared with neural networks, decision trees are easier to understand. Decision tree has low requirements for data preparation, allows the existence of outliers, and has the advantages of fast speed, high precision, and simple generation mode. This article is just the first attempt to apply DM technology to financial early warning research. I believe that with the development of IT, there will be more newer and more accurate data analysis methods applied to the research of financial distress early warning systems.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

All the authors declare that there are no conflicts of interest.

Acknowledgments

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Research Article

Data-Driven Computer Choreography Based on Kinect and 3D Technology

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As a form of artistic expression, dance accompanied by music enriches the cultural life of human beings and stimulates the creative enthusiasm of the public. Choreography is usually done by professional choreographers. It is highly professional and time-consuming. The development of technology is changing the way of artistic creation. The development of motion capture technology and artificial intelligence makes computer-based automatic choreography possible. This paper proposes a method of music choreography based on deep learning. First, we use Kinect to extract and filter actions and get actions with high authenticity and continuity. Then, based on the constant Q transformation, the overall note density and beats per minute (BPM) of the target music are extracted, and preliminary matching is performed with features such as action speed and spatiality, and then, the local features of the music and action segments based on rhythm and intensity are matched. The experimental results show that the method proposed in this paper can effectively synthesize dance movements. The speed and other characteristics of each movement segment in the synthesis result are very uniform, and the overall choreography is more aesthetic.

1. Introduction

Movement is the soul of dance. The first problem that needs to be solved in computer choreography is how to digitize dance movements. Kinect is a somatosensory device released by Microsoft in 2010. Its working principle is to automatically recognize the joint motion data of the human skeleton through infrared rays and capture the skeleton of human motion. Kinect is known as the epoch-making work of the third generation of human-computer interaction technology. In recent years, the use of Kinect for action extraction and then realization of computer dance art has become a research hotspot. In the display of dance, the traditional method is that the choreographer verbally explains or tells the performer by drawing a picture, and then, the dancer shows the specific movement, and subsequent modifications need to be carried out on the actual effect. This requires many repetitive performances by the actors, and the workload is heavy. The use of computer for choreography can show the choreography dance through 3D virtual reality technology so that the choreographer can create, arrange, modify, and preview the effect in the computer in advance. Based on the above technology, it is possible to make simple choreography using a computer.

Many existing motion generation technologies based on machine learning have been applied to dance research, including dimension reduction technology [1], Gaussian process [2], and hidden Markov model [3], so as to capture the potential correlation between music and dance motion characteristics. Dimension reduction technology can map the high-dimensional features of motion to low-dimensional space, so as to capture the potential correlation behind joint rotation in motion capture data [4]. However, the algorithm needs preprocessing steps, such as sequence alignment and fixed data length, and cannot directly model the timeliness of motion data, which limits its application in real dance motion data. Gaussian process late variable models can effectively summarize the changes of human cloud force, but they are not suitable for real-time generation because they require a lot of computing and memory resources [5]. HMM model overcomes the limitations of the two types of models mentioned above, but its ability to capture data changes is limited [6]. In order to solve the defects of computer choreography based on machine learning, this paper will introduce deep learning method to improve the novelty and coherence of generated actions.

2. Methods

2.1. Overview. First of all, the problem that needs to be solved is motion capture based on Kinect. When Kinect captures human body motion data, it captures 20 joint nodes of the human body through infrared rays. As long as you face Kinect and do dance movements, you can record the corresponding raw data. This avoids the need to place sensors on the capturer during traditional motion capture, which hinders the fluency of dance movements. Convert the captured raw data into the BVH file format to save the dance moves. The motion data file in BVH format is one of the standard file formats in the motion capture industry and is widely supported by mainstream animation production software. When using Kinect to collect dance movements, it is conducive to the optimal display and file storage of virtual dances based on the "Principle of Optimal Movements" and "Principle of Minimal Data Simplification" [7].

Secondly, it is necessary to edit and integrate dance movements. Using the 3D software MAYA as the platform, the basic dance moves stored in the BVH format are imported into MAYA for editing. The choreographer can make modifications and combinations based on the existing basic dance moves, such as modifying the angle of the limbs, the speed of a certain movement, and the number of repetitions [8]; at the same time, they can also arrange and integrate the sequence of specific dance moves to express different dance themes. In addition, the choreography of dance emphasizes innovation. Using Kinect equipment, you can capture newly designed dance moves at any time. After converting it into BVH format, it becomes the new basic action element.

Finally, it is necessary to match the skeleton and the character and realize the three-dimensional display. After the preliminary editing of a certain dance movement is completed, the 3D characters can be driven to dance. MAYA provides the function of binding the skeleton to the model so that the 3D model follows the movement of the skeleton. Modify the bound model by adjusting the weight of the model, the size of the skeleton, and other factors so that it can express the dance effect as realistically as possible. For the choreography of large-scale dances, after the choreography of a certain model is completed in advance, the skinned models can be copied and arranged directly to create the ideal formation and stage effect.

2.2. Motion Capture

2.2.1. Two-Dimensional Key Point Recognition Network. The key points of the two-dimensional human body are identified using the Stacked Hourglass Network architecture. This network is constructed by loop nesting of the Hourglass subnetwork. The Hourglass subnetwork is composed of a basic structure called residual module. The residual module structure is shown in Figure 1(a). The input value will pass through the upper and lower paths. This design is inspired by the residual network. The above path is a convolution path, which contains three convolution layers with different sizes of convolution kernels, which are represented by white rectangles in the figure. The three lines of text in the rectangle represent the number of input channels (N_{In}), the size of the convolution kernel (K), and the number of output channels (N_{Out}) from top to bottom. Among the three convolutional layers, there are also batch regularization layers and nonlinear activation layers (RELUs), all of which are represented by gray rectangles. The lower path is a jumper path. This path contains only a convolutional layer with a convolution kernel size of 1×1, which will change the number of channels of the input value, and its output value will be directly added to the output value of the upper path.

The structure of the Hourglass subnetwork is shown in Figure 1(b). Each white rectangle in the figure represents one of the above residual modules. In the upper half, feature extraction is performed continuously, and in the lower half, downsampling is performed through the maximum pooling operation first, and after several residual modules, the nearest neighbor interpolation method is used for upsampling. The two gray rectangles in the figure represent the downsampling and upsampling processes, respectively. It can be seen that there is a dashed line frame in the Hourglass subnet structure diagram. The dashed line frame is replaced by an Hourglass subnet, which is called a second-order Hourglass network. In this study, the Hourglass subnetwork is looped and nested four times for two-dimensional key point detection, namely, the fourth-order Hourglass network.

2.2.2. Three-Dimensional Keypoint Regression Neural Network. After the two-dimensional human body key points are recognized, a set of two-dimensional coordinate values of the human body key points will be output. Then, use this set of two-dimensional coordinates $x \in R^{2n}$ and use the neural network to return to the corresponding set of three-dimensional coordinate values $y \in R^{3n}$. The mapping relationship of the three-dimensional coordinates regressed from the two-dimensional coordinates is $f\colon R^{2n} \longrightarrow R^{3n}$. Optimize the neural network by minimizing the following prediction errors, namely,

$$f^{*} = \min \frac{1}{N} \sum_{i=1}^{N} L\left(f\left(x_i\right) - y_i\right). \tag{1}$$

Among them, L represents the Euclidean distance between vectors as the loss function, N represents the total number of key points to be identified, and f^{*} represents a regression neural network. The structure of the regression neural network model is shown in Figure 2. First, the dimension is converted to 1024 dimensions through a fully connected layer. After that, it passes through the batch regularization layer, the RELUs layer, and the Dropout layer in turn and contains a jump-through path. The structure in the

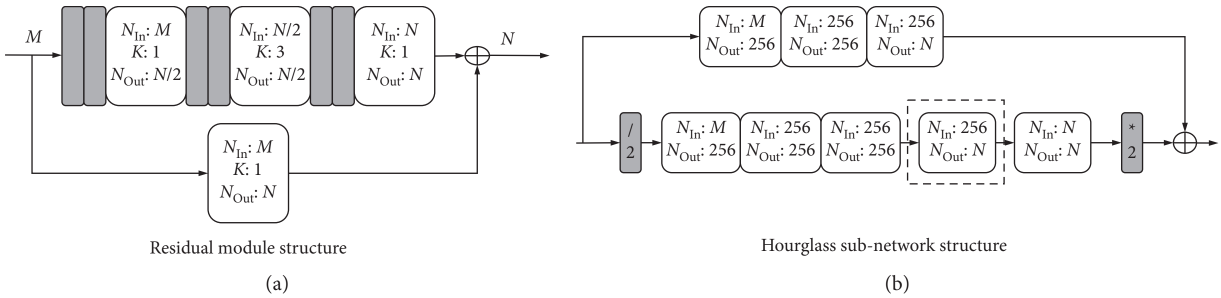


FIGURE 1: Two-dimensional key point recognition network. (a) Residual module structure. (b)Hourglass subnetwork structure.

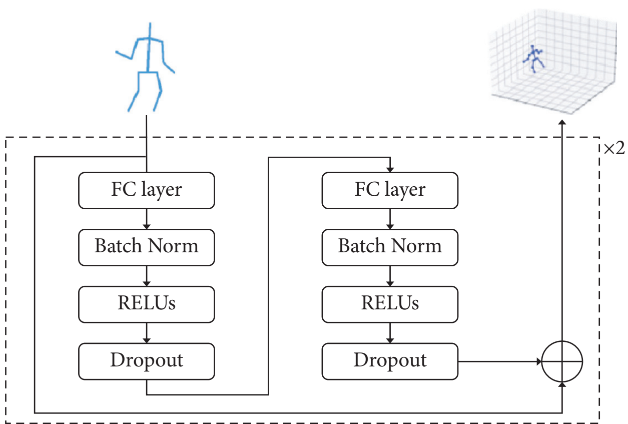


FIGURE 2: Three-dimensional key point regression neural network.

dashed frame in Figure 2 will be repeated once, and finally, a $3n$-dimensional output vector will be formed through a fully connected layer. So far, the three-dimensional coordinates of the key points of the presenter are obtained.

2.3. Action Recurrence. After obtaining the coordinates of the key points of the presenter, they need to be mapped to the robot. The control of the robot takes the angle of each joint as the control command, and the process of using the coordinate value of each key point to calculate the joint angle is called inverse kinematics calculation of the robot. The names of each joint and the actual range of degrees of freedom are shown in Table 1.

In this paper, for each joint of the robot, its angle value is represented by θ_m, and $m\,(m = 1, 2, \ldots, 16)$ is the number of the joint. The $n\,(n = 1, 2, \ldots, 15)$ th key point captured by the motion capture is represented by point p_n, and the vector formed by points p_{n_1} and p_{n_2} is $p_{n_1}p_{n_2}$. The key point numbers detected are shown in Figure 3.

In the angle calculation, there are mainly three situations: the angle between the vector and the vector, the angle between the vector and the plane, and the angle between the plane and the plane [9]. The following examples illustrate the calculation formulas for the three cases.

2.3.1. Calculation of the Angle between the Vector and the Vector. Here we take θ_3 as an example to introduce how to

TABLE 1: List of joints.

Num.	Joint name	Freedom range (°)
1	RShoulderPitch	0~180
2	RShoulderRoll	0~180
3	RElbow	0~180
4	LShoulderPitch	0~180
5	LShoulderRoll	0~180
6	LElbow	0~180
7	RHipRoll	0~180
8	RHipPitch	30~180
9	RKnee	0~150
10	RAnklePitch	90~180
11	RAnkleRoll	70~180
12	LHipRoll	0~180
13	LHipPitch	0~150
14	LKnee	30~180
15	LAnklePitch	0~180
16	LAnkleRoll	0~110

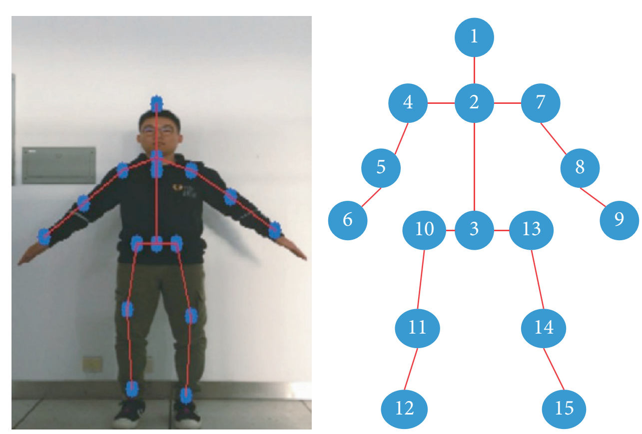


FIGURE 3: Correspondence of feature points.

calculate Relbow. The value of θ_3 is the angle between the vector p_4p_5 and the vector p_5p_6. The calculation formula is

$$\theta_3 = (p_4p_5, p_5p_6) = \arccos\left(\frac{p_4p_5 \cdot p_5p_6}{|p_4p_5||p_5p_6|}\right). \tag{2}$$

2.3.2. Calculation of the Angle between the Vector and the Plane. For example, the angle θ_8 of the joint RHipPitch is the angle between vector $p_{10}p_{11}$ and the plane formed by vectors p_3p_{10} and p_3p_2. To solve θ_8, first use the cross product of p_3p_{10} and p_3p_2 to obtain the normal vector $n_{2,3,10}$ of the plane, then calculate the angle of the normal vector $p_{10}p_{11}$, and then calculate the remaining angles to obtain θ_8:

$$\theta_8 = \frac{\pi}{2} - \left(n_{2,3,10}, p_{10}p_{11}\right) = \frac{\pi}{2} - \arccos\left(\frac{n_{2,3,10} \cdot p_{10}p_{11}}{\left|n_{2,3,10}\right|\left|p_{10}p_{11}\right|}\right). \tag{3}$$

2.3.3. Calculation of the Angle between the Plane and the Plane. For example, if the RShoulderPitch angle θ_1 of the joint is solved, the angle between the plane and the plane is solved. Specifically, first cross-multiply vectors p_5p_6 and p_5p_4 to obtain a plane normal vector $n_{4,5,6}$, then cross-multiply vectors p_2p_4 and p_2p_3 to obtain a normal vector $n_{2,3,4}$ of another plane, and then calculate the angle between the two normal vectors to obtain θ_1:

$$\theta_1 = \left(n_{4,5,6}, n_{2,3,4}\right) = \arccos\left(\frac{n_{4,5,6} \cdot n_{2,3,4}}{\left|n_{4,5,6}\right|\left|n_{2,3,4}\right|}\right). \tag{4}$$

In the calculation process of each angle, due to the selection of the vector direction, it is necessary to find the complementary angle or the complementary angle according to the situation; considering the angle range of each joint, it is necessary to limit the calculated angle value to ensure that it is not exceeding the maximum allowable angle value.

The above calculation process can get all the angle values except the two degrees of freedom of the ankle [10]. For the calculation of the angle of the ankle joint, the relative position of the robot and the ground needs to be taken into consideration because the sole of the foot must be parallel to the ground. As shown in Figure 4, θ_{10} is the angle between the vector $p_{12}p_{11}$ and the plane $\mathrm{Zp}_{10}Y$, and θ_{11} is the angle between the plane where the legs are located and the plane $\mathrm{Zp}_{10}Y$, where the plane and the legs are located is the plane formed by the vectors $p_{12}p_{11}$ and $p_{11}p_{10}$. θ_{15} and θ_{16} can be obtained in the same way.

2.4. Action Selection Algorithm Based on Continuity. Just as a classification model cannot guarantee that the classification accuracy rate reaches 100%, the actions generated by the action generation model also guarantee that every frame generated is a real, coherent, and high-quality action. Therefore, in order to make the generated action suitable for music-based dance choreography, it is necessary to perform a coherence-based action screening first to remove mutation data, so as to ensure that the action data of each frame in an action segment is coherent and improve the quality of the generated action [11].

If an action sequence is coherent, then the actions of adjacent frames in the sequence should have sufficient similarity, which is reflected in the small distance between the corresponding joint points. The motion data used in this article are sampled at a frequency of 30 frames per second. The distance between the corresponding joint point positions in two adjacent frames can be approximated as the speed of the joint at that moment. Because the overall speed

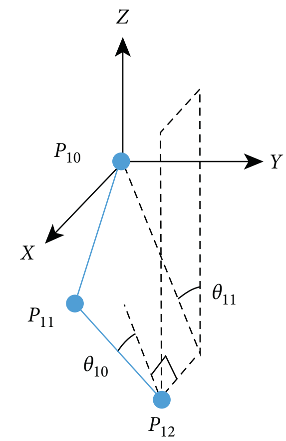


Figure 4: Schematic diagram of ankle joint angle calculation.

of different action sequences is different, it is not easy to judge whether there is a sudden change or a pure rapid movement based solely on the absolute position change [12]. This study believes that, for a coherent action sequence, regardless of the overall speed, the rate of change of the speed between adjacent frames should be small, that is to say, for a sequence with a faster action speed, the instantaneous speed of each frame is higher. For a sequence with a slower action speed, the instantaneous speed of each frame is smaller, but for a continuous action sequence, the speed difference between adjacent frames should be relatively stable.

Therefore, this paper conducts continuous screening of the action sequence based on the rate of speed change. First, calculate the sum of the absolute value of the first-order difference of the joint speeds of adjacent frames:

$$\begin{aligned} V(f) &= \sum_{k=1}^{c} \left|v(f+1,k) - v(f,k)\right|, \\ v(f,k) &= \left\| x_{f+1}^{(k)} - x_f^{(k)} \right\|. \end{aligned} \tag{5}$$

Among them, f is the sequence number of the frame in the action segment N_i, x is the action vector, $x_f^{(k)}$ is the k th dimensional action data of the f th frame, and c is the vector dimension of the action per frame. $v(f,k)$ represents the speed of the kth dimensional data of the fth frame.

Set the maximum threshold $\varepsilon_{\max}$ if the fth frame action satisfies $V(f) \le \varepsilon_{\max}$; the action at that moment meets the continuity requirement. According to the condition, the action sequence is divided, and the continuous action frame that meets the condition is divided into a new action sequence. In order to remove new sequences whose length is too short after segmentation, a minimum length threshold value needs to be set, and only new sequences whose length exceeds this threshold value can be saved in the generated action database.

2.5. Choreography and Composition. Through the feature extraction and matching algorithm of music and action in the previous section, multiple action segments that match the target music have been obtained, and the connectivity constraints between adjacent segments have been met. In this section, on this basis, the adjacent action segments will be transitionally connected to solve the problem of sudden action changes. The action segments will be spliced into a complete sequence of actions to complete the final choreography. The sudden change of action referred to in this section refers to the fact that there is a certain distance between the action at the connection between the action segment and the adjacent action segment N_{i+1}, which causes the directly connected actions to be incoherent, which affects the visual effect of the dance.

This section uses the intermediate frame interpolation algorithm to interpolate between the end k frames of the action segment M and the intermediate action of the action segment N according to the interpolation weight to obtain the final interpolation action. The interpolation action obtained by using this algorithm can realize the natural connection of two action segments and, at the same time, retain the characteristics of the ending action of the previous action segment to a certain extent [13]. The interpolation action ensures the continuity of the action, but there may be unreal actions such as footsteps. In order to avoid the long duration of the interpolation action and affect the perception, the value of k should not be too large. In this study, $k = 14$ is used in the experiment.

Suppose the length of the action segment M is m, the last k frame action is recorded as $M_{m-k+1} = \{f^M_{m-k+1}, f^M_{m-k+2}, \ldots, f^M_m\}$, and the first k frame intermediate action of the action segment N is recorded as $N_{1,\ldots,k} = \{f^N_1, f^N_2, \ldots, f^N_k\}$. First, the starting position of the intermediate action $N_{1,\ldots,k}$ is translated to the same as M_{m-k+1}, and then, the interpolation action $P_{1,\ldots,k}$ is synthesized. Among them, $P_{1,\ldots,k} = \left\{f^P_1, f^P_2, \ldots, f^P_k\right\}$ performs linear interpolation on the node displacement:

$$
\begin{aligned}
p_i^{P,s} &= \alpha(i) f^{M,s}_{m-k+i} + (1 - \alpha(i)) f^{N,s}_i, \quad 1 \le i \le k, \\
\alpha(i) &= 2 \cdot \left(\frac{i}{k}\right)^3 - 3 \cdot \left(\frac{i}{k}\right)^2 + 1, \quad 0 \le i \le k - 1.
\end{aligned}
\tag{6}
$$

Among them, $p_i^{P,s}$ represents the coordinates of the sth joint point of the ith frame of the P action segment, and $\alpha(i)$ is the interpolation weight.

3. Experiments and Results

3.1. Dataset. In recent years, the research on dance movement synthesis is mainly based on motion capture data. At present, the main public motion capture motion datasets are as follows. (1) SBU dataset includes 8 types of actions, a total of 230 sequences of 6614 frames, but the actions in the dataset are all nondance movements such as handshake and punching. (2) HDM05 data set contains about 100 action types, with a total of 2337 sequences of 1840046 frames, but basically all kinds of nondance actions such as walking and kicking. (3) UCY dataset (University of Cyprus), containing a total of 161 sequences 147509 frames, providing dance moves in Greek, Cypriot dance, and other styles, but only 8 of them are relatively complete movements accompanied by music, a total of 28892 frames, and the rest of the sequences are single movement fragments with a short time, which is not conducive to complete dance [14]. (4) The CMU dataset contains a total of 2235 sequences of 98,7341 frames. This is the largest motion capture dataset published so far, covering a wide range of motion types, of which only 64,300 frames are for pure dance movements, with no accompanying music. To sum up, although there are some public exercise datasets, most of them are not dance moves, and there are very few dance moves' data accompanied by music [15]. For the study of the relationship between music and dance movements based on deep learning, movement and music data play a key role in the training of the model.

Therefore, this paper additionally constructs a music-action dataset composed of a complete music choreography sequence. Compared with using professional dancers, it is more economical and convenient to obtain enough dance data through motion capture equipment and download the motion data in VMD format corresponding to different music on the Internet. This paper uses the VMD action files obtained from the Internet and the accompanying WAV music files to construct a music-dance action dataset, with a total of 192 segments, 1057344 frames, and about 587 minutes. Each segment is an independent dance.

The music and dance styles contained in the dataset constructed in this study are not exactly the same, and the speed is also fast and slow. Therefore, it is necessary to classify the actions before performing network training. Based on manual experience, combined with the overall characteristics of the 192 songs and dances in the dataset, the overall style of music and dance can be divided into three categories: modern dance, street dance, and house dance. The overall speed is divided into two categories, fast and slow, for a total of six categories. Since the overall speed of the movement in the same song and dance is not static, for example, the movement is more relaxed at the beginning and end of the song and the movement is more intense at the climax of the song, so the overall dance speed of the entire song is not enough. To classify actions, based on the overall speed of the dance, this study continues to divide movements into fast and slow based on the frame granularity. Based on the above principles, this study manually annotates the constructed dataset. Table 2 shows the number of frames and duration of various actions after classification.

3.2. Model Training and Prediction. In order to obtain good results in deep neural network training, it is necessary to provide sufficient data so that the neural network can fully tap the inner relationship between the data. For the three types of dances, house dance, street dance, and modern dance are included in the dataset constructed in this paper; according to the data volume of different speed movements, this paper trains different movement generation models. During training, 12 Gaussian distributions are used to form a mixed model ($m = 12$), the number of batches (batch size) is set to 100, the sequence length of one-time input is set to 120, the learning rate is 500, and the total training is 500 cycles (epoch), optimized using the RMS Prop optimizer and

Table 2: Detailed information of various types of data in the dataset.

Dance style	Overall speed	Number of fragments	Frame rate	Number of frames	Duration (min)
House dance	Fast	54	Fast	285393	158.6
			Slow	26428	14.7
	Slow	35	Fast	157175	87.3
			Slow	54034	30.0
Street dance	Fast	67	Fast	357287	197.4
			Slow	18048	10.0
	Slow	6	Fast	25504	13.7
			Slow	9063	4.9
Modern dance	Fast	5	Fast	21679	12.6
			Slow	249	0.1
	Slow	25	Fast	41516	22.6
			Slow	56410	31.9

the learning rate is set to 0.01. Table 3 shows the training results at different times.

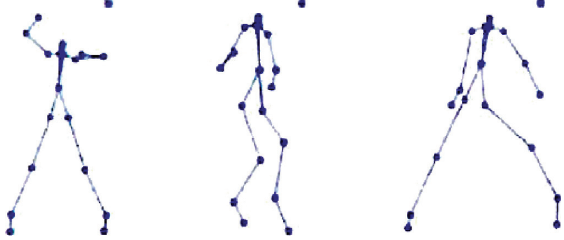
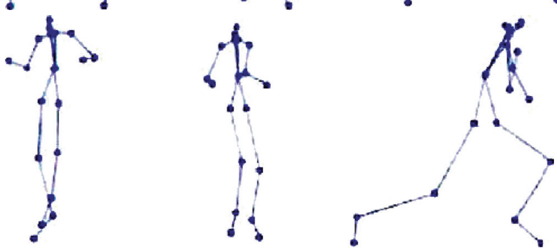
Figure 5 shows the model loss of the training set and validation set during model training. It is worth noting that the error function E^q needs to be minimized during the model training process. Unlike the commonly used loss functions in other networks (such as cross entropy), E^q does not meet the condition of constant greater than zero. Therefore, when the model loss is less than zero, the training process will be terminated in advance, as shown in Figure 5(a). The loss of the validation set and the loss of the training set are inconsistent, and there is even no obvious downward trend. This is because dance movement generation tasks are different from other tasks such as target classification. The choreography and expression of dance moves are not unique. This is where the diversity of dance moves lies. The training process of the movement generation model seeks regularity in it. The diversity and regularity of data are a pair of contradictory standards. Although the actions in the dataset have been preliminarily classified, in the limited dataset, it is difficult to ensure that the verification set selected at random each time has the same law as the training set. Therefore, in the verification set during the first 350 cycles of training, the loss has not changed much. As the model continues to be trained, overfitting occurs, resulting in a sharp increase in the loss of the validation set. You can refer to the loss of the validation set to judge the training situation of the model.

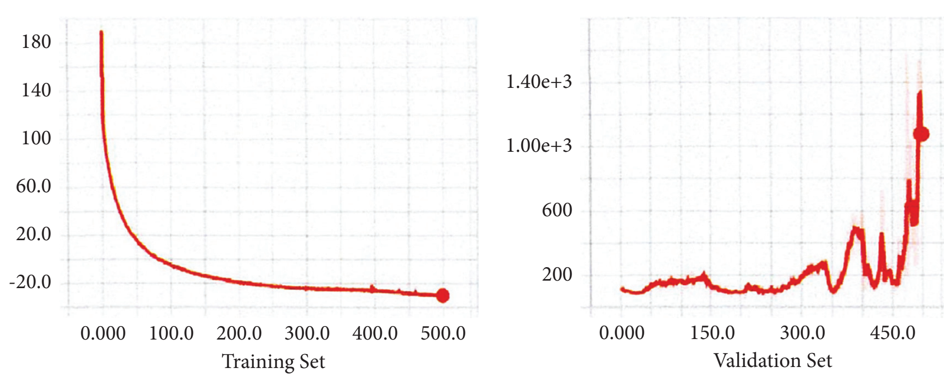
3.3. Qualitative Results. According to the visual effect of the synthesized dance, the choreography result is evaluated, and the effect of the algorithm in this paper is evaluated. First, extract the overall characteristics of "Tokyo Teddy Bear;" after calculation, the BPM value is 126.05, the duration of the change note is 1.93, and the rapid house dance motion generation model is selected to generate the candidate motion database, which is consistent with the user's intuitive hearing. Observing the final dance effect, you can feel that the rhythm and intensity of the dance and the target music match to a certain extent, and the movements are smooth and coherent. Figure 6 shows a posture snapshot of the synthesized dance. Only from the intuitive visual effects, the choreography algorithm in this paper can be considered to be effective.

3.4. Quantitative Results. Experimental purpose: use user ratings to analyze the synthesizing effects of three styles of dance. First, analyze the style of the music according to the overall characteristics of the target music (BPM and the duration of changing notes) and generate the corresponding choreography. This experiment analyzes a number of target music, selects three target music suitable for generating hip-hop, house dance, and modern dance, and choreographs them. The detailed information and overall characteristic values of the target music are shown in Table 4. The test users, respectively, judged the dance styles of the three segments and evaluated the matching degree of music and dance and the continuity and authenticity of dance movements, and the results are shown in Table 5.

From the results, it can be found that the average value of the coherence, authenticity, and matching with music of the three styles of dance are all above 4 points, indicating that users are satisfied with the results of the synthesized dance styles. Therefore, the music choreography algorithm proposed in this paper is Effective. The three indicators of street dance have the highest scores, followed by modern dance, and finally house dance. This study interviewed these users after they completed the test. The users said that the rhythm of hip-hop style movements is obvious and the range of movements is larger, while the range of house dance movements is generally small. Sometimes, it is difficult for users to distinguish between small movements and jitter data. After analysis, the reason why the synthesis result of house dance is worse than that of street dance is that, in the action dataset constructed in this study, the diversity of house dance actions is more abundant, and the concentration of actions is worse than that of street dance, so it is not conducive to the training and learning of the action generation model. Among the 33 users who participated in the score, only 1 user made a wrong judgment on the style of hip-hop and home dance, and the judgments of other users were accurate. After follow-up interviews, the user stated that it was because she did not know the specific concepts of home dance and hip-hop and unable to judge.

Table 3: Action generation results at different times (street dance actions).

Epoch	Time	Generate sample action poses	Describe
1	2.5 min		Unable to generate qualified actions, most joint positions are random, and the outline of the human body can be vaguely seen
50	~2 h		Understand the joint positions and be able to generate basic movements
200	~9 h		The relative relationship of joints is more stable, which can generate richer and more stable movements
500	~22 h		The generated action has unstable continuity and may be overfitting



(a) (b)

Figure 5: Model loss. (a) Training set. (b) Validation set.

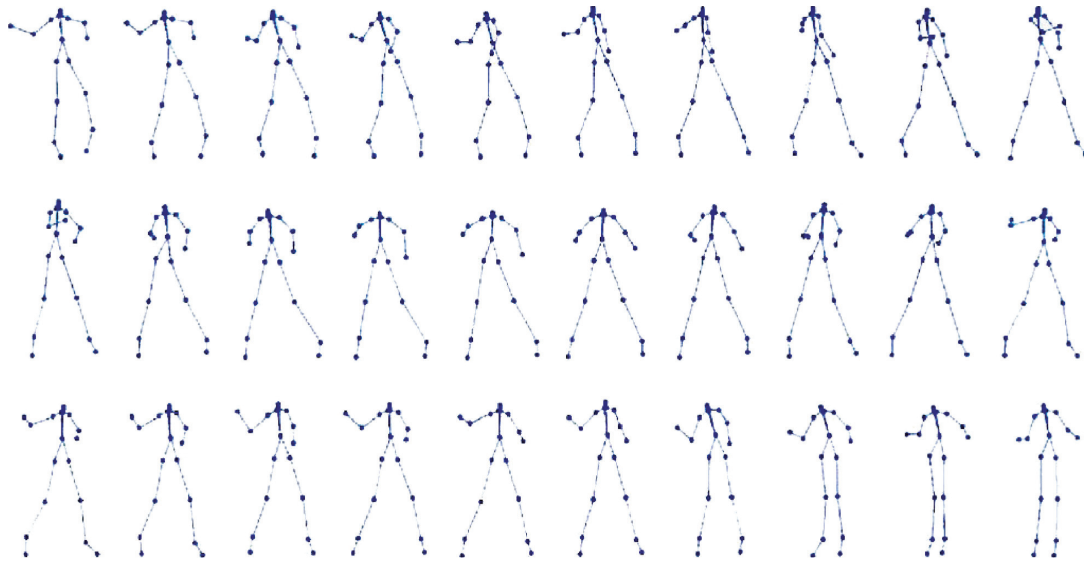


Figure 6: "Tokyo teddy bear" synthetic dance pose snapshot.

Table 4: Details of the three target music.

Music name	Duration	Music BPM	Varying note duration	Dance style
Bad apple	00:05:10	138.6	1.57	Street dance
Chocolate	00:03:46	129.2	1.66	House dance
From Y to Y	00:05:30	96.4	2.54	Modern dance

Table 5: Manual scoring of three styles of dance.

Dance style	Music and dance match	Continuity	Authenticity	Style judgment accuracy (%)
Street dance	4.28 ± 0.10	4.07 ± 0.07	4.04 ± 0.10	96.9
House dance	4.13 ± 0.09	4.05 ± 0.08	4.02 ± 0.08	96.9
Modern dance	4.22 ± 0.11	4.08 ± 0.08	4.08 ± 0.11	100

4. Conclusion

This paper proposes a dance choreography algorithm based on the deep learning model, starting from improving the harmony of music and choreography. First, extract the overall characteristics of the music, including the average duration of BPM and notes, and perform preliminary matching of the action speed characteristics based on this. Then, complete segmentation of music and action sequences and feature extraction of rhythm intensity and combine the results of feature matching and connectability analysis to obtain action sequences that match the target music. Finally, the adjacent action fragments are interpolated to complete the computer music choreography. In this paper, qualitative and quantitative experiments are designed to evaluate the effectiveness of the algorithm. The experimental results show that the local bone movement speed feature extraction algorithm and the dance spatial feature extraction algorithm proposed in this paper can effectively reflect the corresponding characteristics of dance; the overall characteristics of music can accurately reflect the style of music, and the corresponding styles can be synthesized accordingly. Choreographed action: the hierarchical feature matching algorithm is better than the feature matching algorithm based on local rhythm and intensity. The addition of the overall feature matching can synthesize a dance that is more matched to the target music. In the future, it is necessary to further improve the accuracy of the model through the optimization of the model structure to make the generated actions more realistic.

Data Availability

The dataset can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Construction of an Improved English Teaching Model Based on Cellular Automata

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In order to improve the effect of college English teaching reform, this paper puts cellular automata English into English teaching simulation and uses the cellular automata model to study the behavior of complex teaching systems. Moreover, this article uses the method of man-machine combination to establish the corresponding dynamic evolution model and design the local evolution rules of the complex system to simulate the English teaching process, including the movement of students and teachers, the interaction of the teaching process, the development of teaching activities, and the processing of teaching resources. In addition, this paper constructs the functional structure of the system and conducts system verification through experimental research. The experimental research results show that the English classroom teaching evaluation system based on the cellular automaton proposed in this article is very effective, and it has a certain role in promoting English teaching.

1. Introduction

In the process of higher education reform and development, teaching has always been regarded as the core link of higher education, and the quality of teaching can directly reflect the level of teaching in the school. The overall teaching level of national colleges and universities can prove from the side whether the national education guidelines, policies, and systems are correct, thereby further promoting the reform and development of education. For the evaluation of teaching quality, while satisfying the satisfaction of the government and society, all colleges and universities pay more attention to the level of satisfying students. Since the 1980s and 1990s, constructivist learning theories and constructivist teaching theories have become increasingly popular in the West. They all advocate student-centeredness and emphasize that students are processors of information and active constructors of the meaning of knowledge, and the role of teachers is to guide and help. This has brought a great impact on the traditional teacher-centered "filling and filling" teaching view and the learning view of students passively accepting knowledge.

In recent years, with the breakthrough development of software and hardware such as virtual engines, texture rendering, computers, and VR equipment, virtual reality has once again become a hot spot for research and development. Virtual reality technology is an important direction of simulation technology; that is, through computer science technology, the physical and digital data in the physical environment are converted into visual or even touchable 3D virtual scenes, and the combination of computers and peripheral devices allows users to enter the 3D space created by the computer model for perception and interaction [1]. In virtual reality, through diversified interactions such as vision, sound, touch, and operation, users can apply perception experience and cognitive processing capabilities to interact with objects in virtual reality just like in the real world and observe natural changes in the world. Virtual reality uses three elements to construct a virtual reality context [2]: (1) immersion, allowing users to have an "immersive" feeling and blending into the simulated virtual world; (2) interactivity, users passing sensory stimulation and reaction interact with and give feedback to the virtual situation; the system responds to the user in the shortest time and allows the user to feel the response in a simulated situation; (3) conceptual, virtual reality is a fictitious simulated situation. In addition to feeling the sound and light stimulation, you can also conceive of situational design and object attributes and express intangible abstract concepts in concrete forms. Virtual reality has strong flexibility, repetition, and adaptability. People can create the real world from scratch in the computer at a low cost, can repeatedly use virtual reality for training in the same situation, and can quickly learn to use and interact with virtual reality, can realize some areas that cannot be visualized in reality (brain, whole body structure, etc.) and virtual operations, and can obtain reliable information equivalent to the real environment from virtual reality. Another important advantage of virtual reality is safety. Users can make virtual errors and make virtual collisions without harming anyone or themselves. Therefore, virtual reality is widely used in the fields of spatial cognitive assessment, rehabilitation, and psychological research, training, and education. Especially in the field of training and education, because low-cost and high-efficiency virtual reality brings learners an immersive learning environment, enhances the learning experience, bridges the gap between learners and educators in terms of teaching, and makes virtual reality technology, this can help students learn better [3].

Based on the above analysis, this article applies cellular automata to the improvement of English teaching and uses the cellular automata model to study the behavior of complex teaching systems. Moreover, this article uses the method of man-machine combination to establish the corresponding dynamic evolution model and design the local evolution rules of the complex system to improve the teaching effect of colleges and universities.

2. Related Work

Cellular automata simulation is an important method for studying complex systems, and it has been widely used in natural sciences and social sciences. Literature [4] established a cellular automata model for classroom teaching based on the principles of sociology and psychology, and literature [5] simplified the cellular automata model. However, all of its model establishments only looked at the teaching process as the process of knowledge imparting and believed that the amount of knowledge of students should not exceed that of teachers. This is inconsistent with reality, and it is also contrary to the idea of analyzing and researching teaching activities with the viewpoints and methods of complexity science. Literature [5] uses the cellular automata evolution rule of lattice point trend to produce more complicated evolution patterns with fewer evolution rules. Literature [6] believes that a system with a variable evolution rule can better reflect the adaptation of the actual system to environmental changes and studies the chaotic edge effect of a cellular automaton with a variable evolution rule. Inspired by the new cellular automata model, based on the study of the complexity of the university teaching process, based on the driving effect of herd mentality and emotional satisfaction, quality training goals, and education and teaching strategies, the elementary cellular automata and random cellular combining automata establish a cellular automata model of the university teaching process [7].

Literature [8] uses a series of cellular automata models to simulate certain situations and analyze the characteristics of each situation. According to the characteristics of cellular automata, it can be applied to the fields of fluid mechanics and solid mechanics. Literature [9] proposed a method of combining finite element and cellular automata and analyzed the related problems of the fluid-solid interface in composite materials. The movable cellular automata make it possible to simulate complex mechanical systems. Some cellular automata research work has been extended to mechanics, but it should be pointed out that it is compatible with traditional calculation methods (such as finite element method and boundary element method). In comparison, there are few written text introductions related to cellular automata in solid mechanics [10]. As a new exploratory application of cellular automata, literature [11] proposed a simple cellular automata method, which can be combined with finite elements. It should be pointed out that the cellular automata model established above is based on randomly generated free nodes instead of traditional regular grids, and the local rules of cellular automata are based on physical concepts rather than differential equations [12].

There are some results in the research on the evolution law of complex systems based on cellular automata. Literature [13] uses the cellular automata model to develop an intelligent simulation program, which has the ability to simulate the evolution of a complex system. The essence is to simulate the evolution process of simple two-dimensional cellular automata. It allows people to fully realize that simple rules can make cellular automata produce complex evolutionary behaviors. Literature [14] carried out in-depth research on elementary cellular automata through a large number of computer experiments and qualitatively divided the evolutionary behavior of all rules of the cellular automata into four categories from the perspective of dynamic behavior. The method of formal language proves that some rule-evolving languages are formal languages, which explains the complexity of the cellular automata-evolving languages of these rules. Literature [15] proposed the parameter λ to describe the evolution of cellular automata. Through a lot of research, the internal evolution mechanism of cellular automata was revealed, and the concept of "the edge of chaos" was proposed. This concept refers to the bizarre phase transition from "order" to "chaos" in the evolution of cellular automata. Literature [16] divides cellular automata into 6 types, reclassifies stationary cellular automata into zero configuration and fixed type, and divides partial periodic cellular automata into local chaotic types. Literature [17] proposed a power spectrum method to quantitatively describe the evolutionary behavior of cellular automata and found that the evolutionary graph of cellular automata has spatial drift characteristics. Literature [18] studies the evolution properties of certain finite element cellular automata.

3. Establishment of English Teaching Model of Cellular Automata

This model is based on the cellular automata model. The cell space is used to represent the classroom where classroom teaching occurs, the cells are used to represent students, and the various states of cells are used to represent the different effects of students' meaning construction. Each cell has its own meaning construction value through calculation, and there is a mutual influence among cells.

(1) *Cell Space*. A 12×8 matrix is used to represent a classroom. Because in colleges and universities, the interior design of ordinary classrooms is not square but rectangular, so the ordinary model of $m \times m$ is not adopted, but the model of $n \times m$ is adopted, $n \neq m$. Normal classrooms in colleges and universities can generally accommodate about 100 students, so the classroom seats designed in the model are $12 \times 8 = 96$.

(2) *Cells*. A cell represents an individual learner, and an ordered pair (i, j) is used to represent the position of a learner in the cell space, $1 \leq i \leq 8, 1 \leq j \leq 12$. The model assumes that the classroom is full of students, so there are 96 cells in total [19].

(3) *Neighbors*. The neighbor mode of the model refers to the Moore model, that is, the neighbor cell set of the central cell composed of 8 surrounding cells. However, in the model, since the cell space describes a classroom, the form of neighbors will be determined according to the position of the center cell. As shown in Figure 1, the brown cell represents the central cell, and the light gray cell represents the neighbor cell. When the central cell is located at a nonboundary position (such as cell a_{55}), the mode of its neighbor cells is consistent with Moore's neighbor mode. However, when the center cell is located at the boundary of the classroom, the number of neighbor cells will be less than 8. There are two types of boundary positions for the central cell. One is where the cells a_{11}, a_{19}, a_{91}, and a_{99} are located; that is, at the four corners, these cells have only 3 neighbor cells. The other is where the a_{11}, a_{51}, a_{59}, and a_{95} cells are located; that is, at the center point of the boundary, these cells have 5 neighbor cells.

(4) When the cell state set K is selected, $K = \{-1,0,1\}$ represents the cell state set of the model, and the meaning of each state is shown in Table 1. [20].

In the simulation process, the five links of situational teaching are divided into two major links. One is the self-learning link, which includes three links: creating affection, determining problems, and self-learning. Because in these three links, the process of collaborative learning with surrounding students is not involved, the other is the collaborative learning link, which includes two links: collaborative learning and effect evaluation. Because these two links involve the process of discussion and communication, they are the focus of experimental research.

a11	a12	a13	a14	a15	a16	a17	a18	a19
a21	a22	a23	a24	a25	a26	a27	a28	a29
a31	a32	a33	a34	a35	a36	a37	a38	a39
a41	a42	a43	a44	a45	a36	a37	a38	a39
a51	a52	a53	a54	a55	a56	a57	a58	a59
a61	a62	a63	a64	a65	a66	a67	a68	a69

Figure 1: Neighbor mode.

Human behavior is determined by internal eds and external environment. The learner's meaning construction behavior is no exception. It is also affected by internal factors and the external environment. The functional expression of meaning construction is

$$F(t) = F_I(t) + F_O(t). \tag{1}$$

In formula (1), $F_I(t)$ represents the internal factor function thaffects the learner's meaning construction, and $F_O(t)$ represents the environmental factor function that affects the learner's meaning construction, also known as external factors.

The self-learning link focuses on the teacher's guidance and the process of students' self-study. Therefore, the meaning construction effect produced by the students through this link is affected by internal factors, namely, their own knowledge level, and external factors, namely, the teacher's context setting. The following formula can be used to express the meaning construction effect of students in the autonomous learning process.

$$F(t) = F_L(t) + F_S(t). \tag{2}$$

Formula (2) indicates that ignoring other complex factors, the learner's meaning construction function $F(t)$ at time t is the result of the interaction between the student's own knowledge background function $F_L(t)$ and the teacher's context setting function $F_S(t)$.

$F_L(t)$ represents the learner's own knowledge background, also known as the basic level, and represents the knowledge base, knowledge structure, and amount of knowledge that the learner has related to the current content to be learned. Each student has different types of knowledge related to this course, so the value of the learner's own knowledge background function $F_L(t)$ is represented by l, and l is evenly distributed in [0,1]. Each learner has a constant l value during the experiment. The larger the l value, the thicker the learner's knowledge background, which is more conducive to the construction of their own meaning, and vice versa.

Students' meaning-making effects at any moment are the result of a combination of internal and external factors. In free mode collaborative learning without teacher participation, the meaning construction effect of student (i, j) at moment t is related to the student's own meaning construction effect at moment $t-1$ (internal factors) and the

Table 1: The meaning of each state of the cell.

Condition	Implication
$K_{i,j} = -1$	Meaning construction does not meet the standard, and the learning quality of learners in this state does not meet the minimum requirements of the teacher
$K_{i,j} = 0$	Meaning construction meets the standard, and the learning quality of learners is average, between substandard and excellent
$K_{i,j} = 1$	Meaning construction is excellent, the learner's learning quality is very good, and it can meet the teacher's teaching expectations

meaning construction effect of surrounding students at moment $t-1$ (external factors).

$$F_{i,j}(t) = \alpha \times F_{i,j}(t-1) + \beta \times \sum_{n=1}^{n=n^*} F_n(t-1) \div n^*. \tag{3}$$

As shown in formula (3), $F_{i,j}(t)$ represents the meaning construction effect of students (i,j) at time $t-1$, and $F_{i,j}(t-1)$ represents the meaning construction situation of students (i,j) at time $t-1$. The formula $\sum_{n=1}^{n=n^*} F_n(t-1) \div n^*$ indicates that the students (i,j) are affected by the meaning construction effect of surrounding students at time $t-1$, which is represented by the average influence of neighbor cells on the central cell in the model. Among them, n represents the n-th neighbor cell of the central cell (i,j), and n^* represents the number of neighbor cells. Depending on the position of the central cell, the number of neighbor cells may be 3, 5, or 8, so there are three possible values for n^*. $F_n(t-1)$ represents the meaning construction of the n-th neighbor cell.

α and β are, respectively, the weights of internal factors and external factors on the meaning construction of learners, and they are all the weights of first-level indicators. The first-level indicator system of this evaluation is $\{W_e | e = 1, 2\}$, and its corresponding weight system is $\{V_e | e = 1, 2\}$, $0 < V_e \leq 1$, and it satisfies $V_I + V_2 = 1$. Among them, W_1 represents the effect of internal factors, V_I represents its weight, and $\alpha = V_I$; W_2 represents the influence of external factors, V_2 represents its weight, and $\beta = V_2$. Through the subjective experience method, it can be known that when students have poor meaning construction effects, they are more susceptible to environmental factors; when students have good meaning construction effects, they are not easy to be affected by environmental factors. Therefore, the value of the weight system is changed according to the state of the cell.

When $K_{ij} = -1$, it means that the learner's meaning construction is not up to the standard, and he is more susceptible to external factors, so $\alpha = 0.3, \beta = 0.7$. [21].

When $K_{i,j} = 1$, it means that the learner has a good sense-building effect, and he is more susceptible to internal factors and not easy to be affected by the external environment, so $\alpha = 0.7, \beta = 0.3$.

When $K_{i,j} = 0$, it means that the learner's meaning construction effect is average, and it is affected by internal and external factors with equal strength, so $\alpha = 0.5, \beta = 0.5$.

The formula after finishing is as follows:

$$\begin{cases} F_{i,j}(t) = 0.3 \times F_{i,j}(t-1) + 0.7 \times \sum_{n=1}^{n=n^*} F_n(t-1) \div n^*, & K_{i,j}^{t-1} = -1, \\ F_{i,j}(t) = 0.5 \times F_{i,j}(t-1) + 0.5 \times \sum_{n=1}^{n=n^*} F_n(t-1) \div n^*, & K_{i,j}^{t-1} = 0, \\ F_{i,j}(t) = 0.7 \times F_{i,j}(t-1) + 0.3 \times \sum_{n=1}^{n=n^*} F_n(t-1) \div n^*, & K_{i,j}^{t-1} = 1. \end{cases} \tag{4}$$

In the process of collaborative learning, it is impossible for every student to have the opportunity to communicate with the teacher. Therefore, most students are still in a situation where they have not communicated with the teacher. When students cannot get the guidance of teachers in the process of collaborative learning, the expression of the meaning construction effect is consistent with formula (4). When students get the opportunity to communicate with teachers in the process of collaborative learning, the student's meaning construction effect function is shown in

$$F_{i,j}(t) = \alpha \times F_{i,j}(t-1) + \beta \times \sum_{n=1}^{n=n^*} F_n(t-1) \div n^* + \lambda. \tag{5}$$

The state of the central cell still determines the value of the first-level weights α and β, and the value method is consistent with the value method without teacher participation. After sorting, the expression of the student meaning construction function with teacher participation is shown in

$$\begin{cases} F_{i,j}(t) = 0.3 \times F_{i,j}(t-1) + 0.7 \times \sum_{n=1}^{n=n^*} F_n(t-1) \div n^* + \lambda, & K_{i,j}^{t-1} = -1, \\ F_{i,j}(t) = 0.5 \times F_{i,j}(t-1) + 0.5 \times \sum_{n=1}^{n=n^*} F_n(t-1) \div n^* + \lambda, & K_{i,j}^{t-1} = 0, \\ F_{i,j}(t) = 0.7 \times F_{i,j}(t-1) + 0.3 \times \sum_{n=1}^{n=n^*} F_n(t-1) \div n^* + \lambda, & K_{i,j}^{t-1} = 1. \end{cases} \tag{6}$$

Unlike the free model of collaborative learning, the group model of collaborative learning has a very clear collaborative learning group, that is, group members. In the collaborative learning group, the leader of the group—the group leader—is arranged, and the group leader plays a leadership role, and he plays a key role in the collaborative learning of the whole group. Under the leadership of the group leader, the group members will have an orderly discussion. In fact, dividing the group is to divide the whole class, a large collective, into smaller groups that are almost identical to its model, in which the group leader acts as the teacher in the larger group.

In the actual teaching process, when teachers use the subgroup mode for collaborative learning, each group generally has 4 to 6 members. This experiment will choose the 6-person group mode. Because there are 96 students in the class, the class is divided into 16 groups.

As shown in Figure 2(a), the 6 students in the dark gray area are a group, and the 6 students in the light gray area are another group, a total of 16 groups. The diagonal line in each group represents the group leader. Each team has two types of members, and one is the leader and the other is the member.

For the group leader (i, j), the internal factor affecting his meaning construction at moment t is the group leader's meaning construction at moment $t-1$, and the external factor is the average meaning construction effect of the five group members at moment $t-1$, as shown in Figure 2(b). Therefore, the meaning construction function at moment t is shown in

$$F_{i,j}^{g}(t) = \alpha \times F_{i,j}(t-1) + \beta \times \sum_{n=1}^{n=n^*} F_n(t-1) \div n^*. \tag{7}$$

In formula (7), $F_{i,j}^{g}(t)$ means that the student (i, j) is the group leader, and the value of n^* can be determined here. Because each group leader has 5 group members, $n^* = 5$, the weight value of the group leader's internal and external factors is still affected by his own state, and the value is consistent with the value method in the no-group mode. After finishing, formula (8) is obtained.

$$\begin{cases} F_{i,j}^{g}(t) = 0.3 \times F_{i,j}(t-1) + 0.7 \times \sum_{n=1}^{n=5} F_n(t-1) \div 5, & K_{i,j}^{t-1} = -1, \\ F_{i,j}^{g}(t) = 0.5 \times F_{i,j}(t-1) + 0.5 \times \sum_{n=1}^{n=5} F_n(t-1) \div 5, & K_{i,j}^{t-1} = 0, \\ F_{i,j}^{g}(t) = 0.7 \times F_{i,j}(t-1) + 0.3 \times \sum_{n=1}^{n=5} F_n(t-1) \div 5, & K_{i,j}^{t-1} = 1. \end{cases} \tag{8}$$

For a group member (i, j), the internal factor that affects the meaning construction of the group member at time t is the group member's meaning construction situation at time $t-1$. There are two external factors here. One is the meaning construction effect of the team leader at time $t-1$, and the other is the average meaning construction effect of the remaining 4 team members at time $t-1$. As shown in Figure 2(c), the gray squares represent group members (i, j). Since the team leader is at the core of the team, the team leader's influence on the team members is greater than the other four team members' influence on the team members in terms of external factors. Here, a secondary weight will be introduced to describe the influence of the two external factors on the meaning construction of group members, as shown in

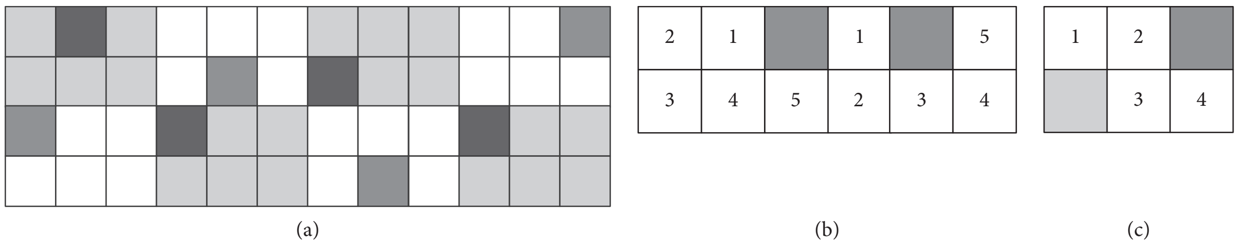

Figure 2: Schematic diagram of the cell. (a) Grouping diagram. (b) Schematic diagram of the external factors of the team leader. (c) Schematic diagram of the external factors of the team members.

$$F_{i,j}(t) = \alpha \times F_{i,j}(t-1) + \beta \times \left(\gamma \times F_{i,j}^{g^*}(t-1) + \delta \times \sum_{n=1}^{n=n^*} F_n(t-1) \div n^* \right). \tag{9}$$

In formula (9), the function $F_{i,j}^{g}(t-1)$ represents the meaning construction effect of the group leader in the group to which the group members (i, j) belong at the time t–1. The formula $\sum_{n=1}^{n=n^*} F_n(t-1) \div n^*$ represents the influence of the average meaning construction of other group members in the group to which the group member (i, j) belongs. It is certain that $n^* = 4$ here.

In formula (9), γ and δ, respectively, represent the weight value of the influence of the group leader's meaning construction situation and the group member's meaning construction situation on the group member's (i, j) meaning construction in the external factors. In equation (9), α and β belong to the first-level weight, γ and δ belong to the second-level weight, and they satisfy

$$\alpha \times \beta \times (\gamma + \delta) = 1. \tag{10}$$

In formula (10), α and β still represent the weight values of internal factors and external factors, and their values are still affected by the cell state, and their values are consistent with the previous text. In order to highlight the core role of the team leader, by referring to the values of α and β in the previous article, we set $\gamma = 0.7$ and $\delta = 0.3$. Formula (11) is obtained by sorting.

$$\begin{cases} F_{i,j}(t) = 0.3 \times F_{i,j}(t-1) + 0.7 \times \left(0.7 \times F_{i,j}^{g*}(t-1) + 0.3 \times \sum_{n=1}^{n=4} F_n(t-1) \div 4 \right), & K_{i,j}^{t-1} = -1, \\ F_{i,j}(t) = 0.5 \times F_{i,j}(t-1) + 0.5 \times \left(0.7 \times F_{i,j}^{g*}(t-1) + 0.3 \times \sum_{n=1}^{n=4} F_n(t-1) \div 4 \right), & K_{i,j}^{t-1} = 0, \\ F_{i,j}(t) = 0.7 \times F_{i,j}(t-1) + 0.3 \times \left(0.7 \times F_{i,j}^{g*}(t-1) + 0.3 \times \sum_{n=1}^{n=4} F_n(t-1) \div 4 \right), & K_{i,j}^{t-1} = 1. \end{cases} \tag{11}$$

The evolution starts with the initialization of all metacells so that each metacell has its own state. For an average class in reality, there are always basic good, average, and poor students in the class, and the number of good, average, and poor students in an average class has a distribution pattern of small at the end and large in the middle. A study of the student structure of a class in this college showed that the ratio of the number of good, average, and poor students was $2:5:2$. Before the lecture started, that is, at $t = -0$, learners possessed their respective knowledge background levels, and students with good, medium, and poor knowledge background levels were defaulted to students with good, medium, and poor levels of meaning construction in the experiment during initialization. At $t = 0$, the system randomly assigned l values, $l \in [0, 1]$, to each tuple to distinguish students' basic levels. In order to express the proportion of the three types of students in the general class more accurately, the three types of students can be identified according to the range of values l, and the ratio of the number of the three types of students is $2:5:2$, as shown in Table 2.

In the process of evolution, the state of the cell is determined by judging the meaning of each cell to construct the function value $F_{i,j}(t)$. The specific situation is shown in Table 3. The results in Table 3 are derived from the reasoning and calculations in Tables 4 and 5.

The conversion conditions were determined based on the students' own knowledge background function $F_L(t)$ and the values of the teacher's context setting function $F_S(t)$. Because both functions take values in the range [0, 1], in the initialization, students with $l < 0.22$ are classified as students with poor knowledge background, students with $l > 0.78$ are classified as students with good knowledge background, and

Table 2: Judgment criteria for three types of students in initialization.

	Poor students $K_{i,j} = -1$	Ordinary student $K_{i,j} = 0$	Excellent student $K_{i,j} = 1$
The value of l	$l < 0.22$	$0.78 \geq 1 \geq 0.22$	$l > 0.78$
Student number	22	52	22

Table 3: State transition rules.

The state of the cell (i, j) at time t-1	$K_{i,j}^{t-1} = -1$ or $K_{i,j}^{t-1} = 0$ or $K_{i,j}^{t-1} = 1$		
Transition condition	$F_{i,j}(t) < 0.72$	$1.28 \geq F_{i,j}(t) \geq 0.72$	$F_{i,j}(t) > 1.28$
The state of the cell (i, j) at time t	$K_{i,j}^{t} = -1$	$K_{i,j}^{t} = 0$	$K_{i,j}^{t} = 1$

Table 4: Breakdown table of student types and context setting effects obtained.

Level	Poor	Ordinary		Good
		Less good	Higher good	
Knowledge background	$l < 0.220$	$0.5 \geq l \geq 0.220$	$0.78 \geq l > 0.50$	$l > 0.780$
Situational setting effect obtained	$s < 0.220$	$0.5 \geq s \geq 0.220$	$0.78 \geq s > 0.50$	$s > 0.780$

Table 5: The value range of the meaning construction function.

$f(l_{i,j}, s_{i,j})$	$K_{i,j}$	$F_{i,j}(t)$'s value range	Total range of values of $F_{i,j}(t)$
F (poor, poor)	−1.0	[0.0,0.440)	
F (poor, worse)	−1.0	[0.220,0.720)	[0,0.720)
F (worse, poor)	−1.0	[0.220,0.720)	
F (poor, good)	0.0	(0.780,1.220)	
F (worse, better)	0.0	(0.720,1.280]	[0.72,1.280]
F (better, worse)	0.0	(0.72,1.280]	
F (good, poor)	0.0	(0.780,1.220)	
F (better, good)	1.0	(1.280,1.780]	
F (good, better)	1.0	(1.280,1.780]	(1.28,2.0]
F (good, good)	1.0	(1.560,2.0]	

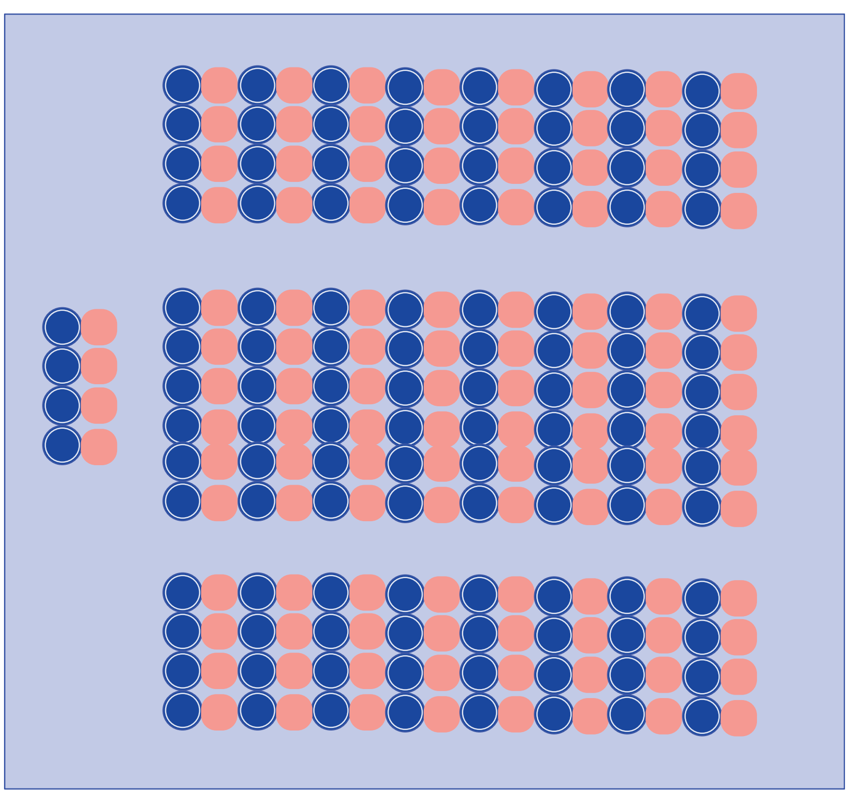

Figure 3: The initial distribution of people in the classroom.

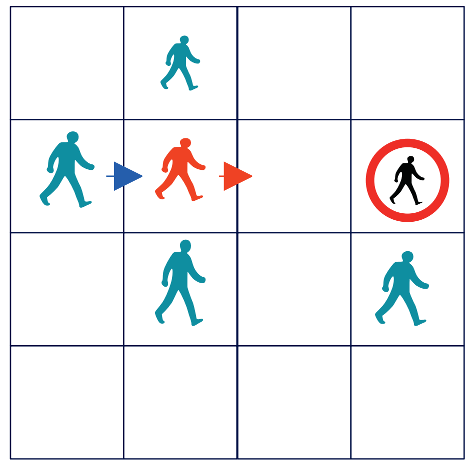

Figure 4: Interaction between pedestrians.

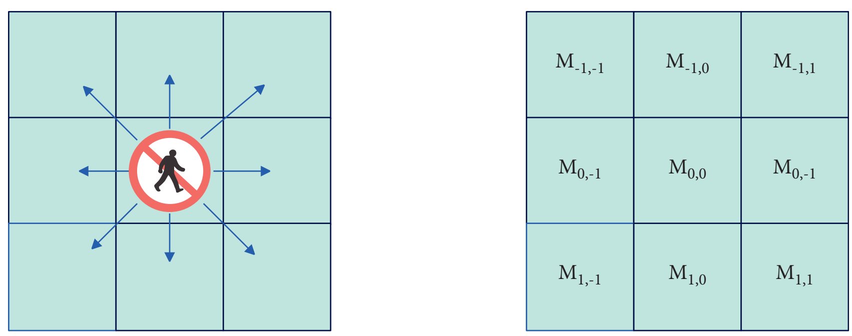

Figure 5: Pedestrian particle movement matrix.

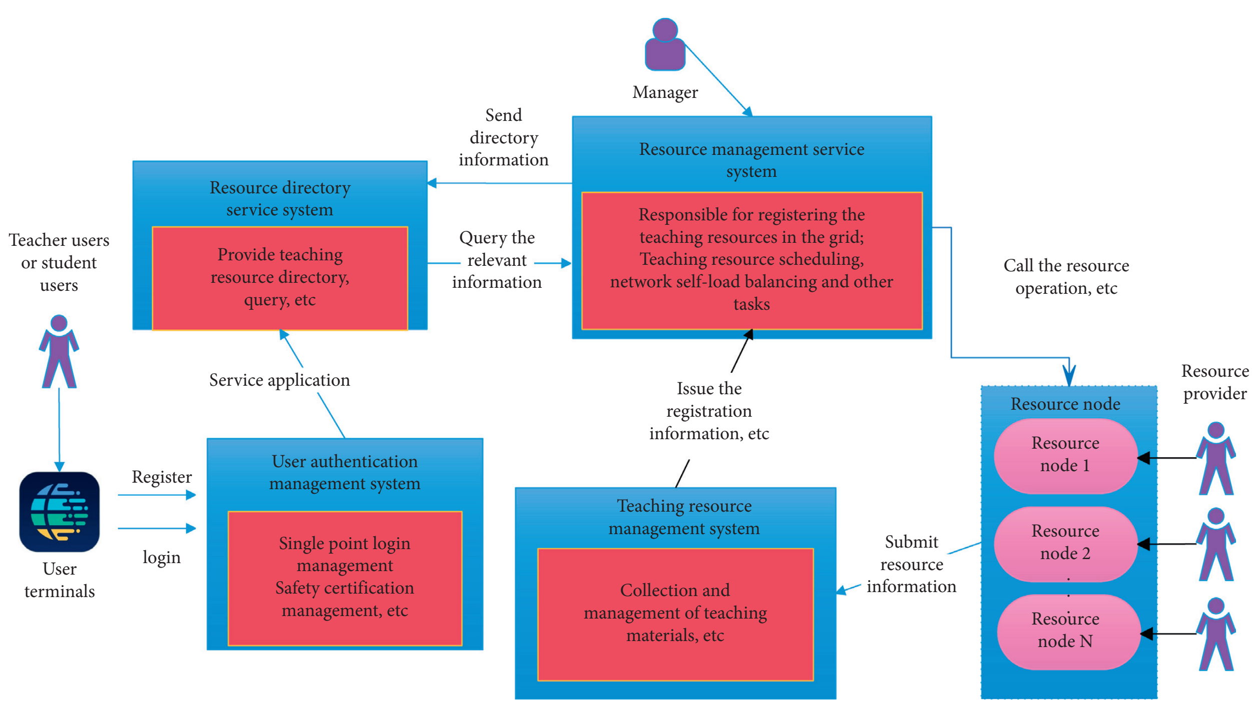

Figure 6: English teaching system model based on cellular automata.

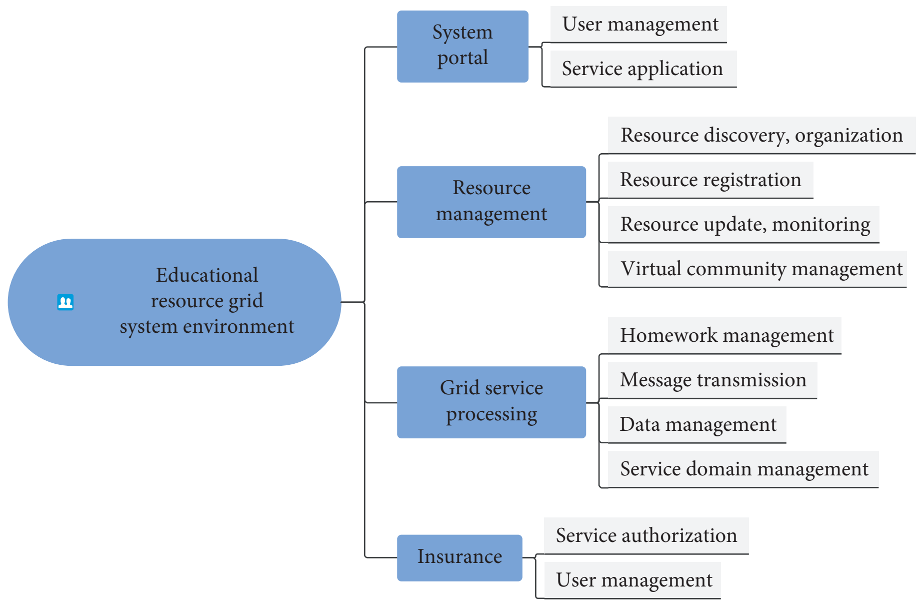

Figure 7: Logical function of English education resource sharing service based on cellular automata.

Table 6: Teaching simulation evaluation of English classroom teaching evaluation system based on cellular automata.

No	Simulation evaluation
1	87.92
2	88.52
3	77.87
4	86.06
5	81.82
6	85.11
7	80.04
8	85.73
9	85.35
10	86.92
11	88.54
12	80.90
13	79.96
14	89.21
15	90.38
16	77.49
17	81.85
18	83.39
19	89.25
20	79.84
21	78.08
22	77.95
23	80.25
24	89.48
25	84.41
26	80.09
27	77.83
28	84.17
29	81.25
30	89.73
31	86.18
32	78.58
33	90.25
34	83.59
35	88.34
36	80.72
37	89.54
38	88.39
39	86.78
40	87.31
41	81.38
42	89.35
43	85.82
44	80.58
45	81.06
46	79.40
47	88.56
48	90.45
49	89.61
50	83.50

students with $0.78 \geq l \geq 0.22$ are classified as students with average knowledge background. Referring to the practice of classifying students into three categories by the value of l, students were also classified into three levels in the experiment with respect to the value of s at which they obtained the effect of contextualization. Similarly, students with $S < 0.22$ were classified as students with poor contextualization, students with $s > 0.78$ were classified as students with good contextualization, and students with $0.78 \geq S \geq 0.22$ were classified as students with average contextualization. In order to investigate the effects of these two functions on students' meaning construction effects in detail, it is necessary to further subdivide the students with average knowledge background and those who obtained average context setting effects, as shown in Table 4.

Before the collaborative learning, the student's meaning construction function is determined by the student's own knowledge background function $F_L(t)$ and the teacher's context setting function $F_S(t)$, and the value of the meaning construction function determines the student's state. Therefore, the status of the student is determined by the

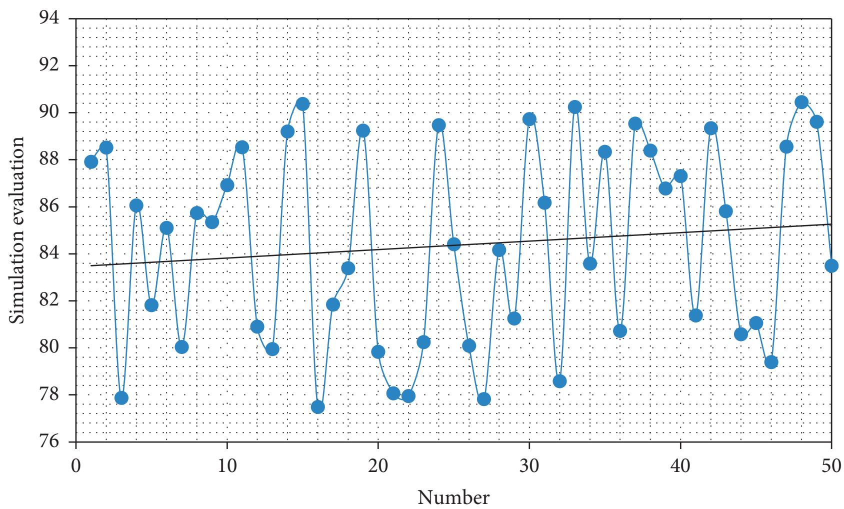

Figure 8: The simulation effect of the English classroom teaching evaluation system based on cellular automata.

Table 7: The teaching effect evaluation of the English classroom teaching evaluation system.

No	Teaching effect
1	92.35
2	82.35
3	82.39
4	85.14
5	91.16
6	86.59
7	81.75
8	91.76
9	86.76
10	91.95
11	88.18
12	91.98
13	85.19
14	89.75
15	84.62
16	90.60
17	83.17
18	90.26
19	89.96
20	88.02
21	87.61
22	88.28
23	92.03
24	90.38
25	85.33
26	85.15
27	82.43
28	85.69
29	86.54
30	86.05
31	87.12
32	86.79
33	81.18
34	91.02
35	87.42
36	81.86
37	89.25
38	85.71
39	88.74
40	87.84
41	92.36
42	82.99
43	81.76
44	81.46
45	82.06
46	85.44
47	92.26
48	83.84
49	89.09
50	88.85

student's own knowledge background and the effect of the teacher's situation setting. The relationship between the student's status and the student's own knowledge background and the effect of the teacher's context setting is shown in

$$K_{i,j} = f\left(l_{i,j}, s_{i,j}\right). \tag{12}$$

Formula (12) indicates that the state of the student can be determined according to the student's own knowledge background and the effect of the teacher's context setting.

Because l can represent students with 4 kinds of knowledge backgrounds, and s can represent students with 4 kinds of context setting effects, so the combination of l and s has $4 \times 4 = 16$ situations. The regulations are as follows:

(i) f (poor, poor) $= -1$;

(ii) f (poor, worse) $= -1$;

(iii) f (poor, better) = uncertain;

(iv) f (poor, good) $= 0$;

(v) f (worse, poor) $= -1$.

(vi) f (worse, worse) = uncertain.

(vii) f (worse, better) $= 0$.

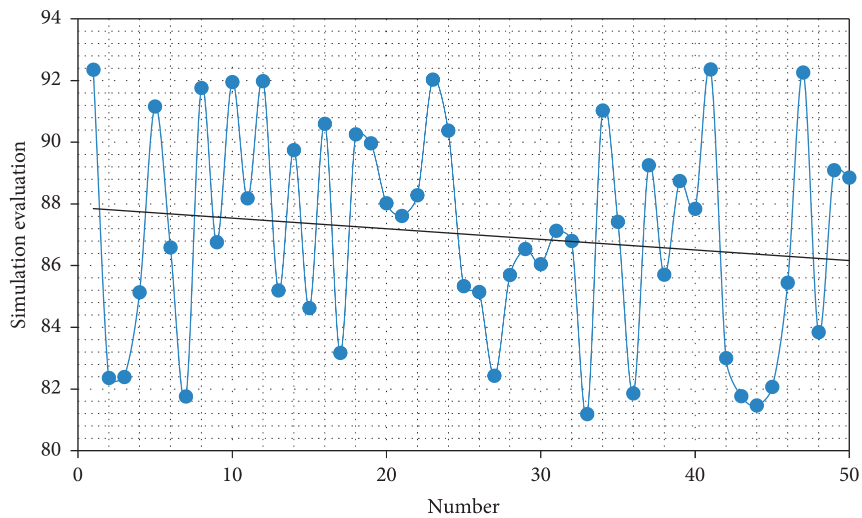

FIGURE 9: Statistical diagram of the teaching effect of the English classroom teaching evaluation system.

(viii) f (worse, better) = uncertain.

(ix) f (better, worse) = uncertain.

(x) f (better, worse) = 0.

(xi) f (better, better) = uncertain.

(xii) f (better, good) = 1.

(xiii) f (good, poor) = 0.

(xiv) f (good, worse) = uncertain.

(xv) f (good, better) −1.

(xvi) f (good, good) = 1.

For the 10 cases in which the state can be determined among the 16 cases, the range of values of the meaning construct function can be calculated by equation (1), as shown in Table 5.

Through the display in Table 5, the state transition rules in Table 3 can be summarized.

4. Construction of an Improved English Teaching Model Based on Cellular Automata

After the grid information is recorded, it is necessary to set the grids occupied by different areas, and the typical areas are classrooms, corridors, and stairs. Different areas and grids can be used to initialize the distribution of people, and at the same time, the distribution of people can be counted to analyze and evaluate the evacuation process. The teaching building is used as a place for students to attend classes, and the personnel can be initialized and distributed based on the classroom curriculum. Each classroom contains information about desks and chairs (as shown in Figure 3). The number of desks and chairs is the maximum capacity of the classroom, and people can be distributed behind the desks and chairs to simulate a real situation.

In Figure 4, the circle represents the pedestrian, the square represents the obstacle, and the arrow represents the direction of the pedestrian's moving speed. We use the red pedestrian as an example. Since he is at the opposite speed from the pedestrians on both sides, he will be subject to the friction of the two pedestrians against him, which will hinder his movement. Moreover, the pedestrians behind him move in the same direction as him, and he will be pushed by the pedestrians behind him.

To sum up, after abstracting pedestrians into particles, each pedestrian particle has a moving direction in the mobile mode. According to the direction, a 3×3 matrix M can be constructed for each particle. The elements in the matrix represent the size of the expected velocity value in the direction (i, j) of the particle, as shown in Figure 5.

As shown in Figure 6, the English teaching system model based on cellular automata consists of six parts: client, resource node, user authentication management service system, teaching resource management system, resource catalog service system, and resource management service system.

The construction of the cellular automata-based English teaching model educational resource grid configuration information platform can not only manage various resources uniformly but also provide users with safe and transparent grid services more conveniently, as shown in Figure 7.

After constructing the above model system structure, the performance of the system is verified. The system in this paper can be used to simulate the English teaching process, including the movement of students and teachers, the interaction of the teaching process, the development of teaching activities, and the processing of teaching resources. Therefore, this article combines the actual situation to deal with it systematically and, from the actual situation, design experiments to study the simulation effect of this system on English classroom teaching and obtain the results shown in Table 6 and Figure 8.

From the above test evaluation, it can be seen that the teaching effect of the English classroom teaching evaluation system based on the cellular automaton proposed in this paper is good. On this basis, the teaching effect of this system is evaluated, and the results shown in Table 7 and Figure 9 are obtained.

From the above research, we can see that the English classroom teaching evaluation system proposed in this article has a very good teaching effect and has a certain role in promoting English teaching.

5. Conclusion

The teacher evaluation system designed by colleges and universities for students, the establishment of rich elective courses, and the opening of "green channels" for students to reflect the various teaching problems of the school all reflect the main status of students, and colleges and universities gradually treat students as an object for service. Similar to the pursuit of customer satisfaction by businesses, the school also considers student satisfaction as a core indicator to reflect on its own performance. Moreover, English teaching needs to be improved through the use of intelligent methods to assist teaching and to change the traditional teaching mode. This article applies cellular automata to the improvement of English teaching and uses the cellular automata model to study the behavior of complex teaching systems. In addition, this paper uses the method of man-machine combination to establish the corresponding dynamic evolution model. Finally, this paper constructs an intelligent simulation system and then designs experiments to conduct system evaluation. The experimental research results show that the teaching effect of the English classroom teaching evaluation system based on the cellular automaton proposed in this article is very good, and it has a certain role in promoting English teaching.

Data Availability

The labeled dataset used to support the findings of this study is available from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

Acknowledgments

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Research Article

Design of Commercial Building Complex Based on 3D Landscape Interaction

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The needs of visualization of multidimensional information of the earth, 3D virtual construction, and engineering design are driving research into some technologies of 3D landscape interactive design. The function and availability of the 3D landscape interactive system are largely determined by an efficient interactive algorithm, which is an essential part of the interactive design system of commercial architecture landscape. This paper investigates and evaluates the current state of 3D landscape intersection in landscape design, compares and evaluates existing 3D landscape modeling methods, and proposes some recommendations for the feasibility of a 3D commercial building performance scheme that will serve as a model for future large-scale urban commercial building landscape modeling. When the landscape is represented by objective substances like visual images, people are more likely to actively engage with nature and make automatic decisions based on physiological responses. The introduction of 3D technology has given people's lives a new lease on life, and it is critical to optimize urban planning and management.

1. Introduction

Today's society is rapidly entering a digital world, thanks to advances in global informatization and the development of digital technology, computer software and hardware, database technology, network information industry, database technology, computing graphics and images, virtual reality technology, and so on [1]. The city provides the necessary space for human production and life, that is, urban space, as a relatively concentrated area of human life on the earth [2]. Everything has its own three-dimensional spatial information in reality, which is a true three-dimensional geometric space. It is necessary to create a three-dimensional landscape model of the city in order to express and process the three-dimensional data of urban space [3]. Commercial complexes can provide more convenient centralized living areas based on the needs of users to adapt to the fast-paced urban development [4]. Diversified retail businesses that are closely related to life disrupt the traditional residential business environment model and create a brand new integrated business model of urban agglomeration based on life, pleasure, and a variety of choices [5]. Urban complex is the product of urbanization. It is composed of social living spaces with different properties and uses in the city. Through the introduction of urban public space, it comprehensively combines various scattered spaces, gives full play to the coordination of architectural space and the complementary role of architectural functions, and shows great vitality and abundant development potential [6].

As the social economy has grown, a new commercial format has been introduced from abroad, as evidenced by its name. The urban commercial complex is a significant commercial center in a city, and its significance has outstripped the general concept of structures [7, 8]. There will be a variety of feature models as well as complex and changeable geomorphic models throughout the city. To improve modeling efficiency and quality, we must choose appropriate modeling methods for various features and geomorphology. In this paper, the performance of 3D architecture in landscape design is taken as the main starting point, and the information obtained from field investigation is taken as the main source of thesis materials, and analysis and suggestions are made in the form of investigation report. This paper studies and analyzes the performance status of 3D landscape intersection in landscape design, and puts forward some suggestions on the feasibility of 3D commercial building performance scheme. The existing three-dimensional landscape modeling methods are compared and analyzed, and their respective characteristics are summarized, so as to provide reference for future large-scale urban commercial building landscape modeling.

Commercial complex itself has many characteristics such as intensification and unity. At present, it is favored by many consumer groups. It is under this background that urban commercial complex architecture has developed rapidly in China in recent years [9]. With the development of commercial architecture performance technology, it not only produces new things, but also makes outstanding contributions to social reform [10]. The performance art of commercial architecture is particularly important [11]. The three-dimensional landscape interactive design method gives the three-dimensional virtual scene of urban landscape, so that designers can deal with the virtual environment flexibly and creatively, establish effective information exchange and interaction between information map and human vision, and carry out knowledge mining [12].

2. Related Work

In literature [11], based on the principle and classification of landscape model expression in urban 3D geographic information system, a batch 3D model construction method of symbol matching and triangulation was proposed for abstract point, line, and area objects, and a set of rapid 3D model construction tools was developed based on this method. Literature [13] points out that the performance of landscape images needs a deeper definition to show them, which is the process that can finally realize the whole view. Literature [14] points out that urban commercial animation is not only a work of art with originality, aesthetics, image, and emotion, but also a commodity and a special cultural product. In literature [15], based on 2DGIS, a 3D city map was developed, and the building model within the city was built with simple geometry. Literature [16] puts forward the idea of establishing the 3D model base of urban landscape to realize the rapid reconstruction of urban 3D landscape. Literature [17] mentioned in the research that, in the process of urban construction, we should maintain the existing urban history and culture, do a good job in the publicity and popularization of urban history and culture, and create a strong urban cultural atmosphere and noble urban humanistic spirit.

Literature [18] discusses the scientific and technological expression methods of landscape design. In order to meet the requirements of the new world and people's fast-paced lifestyle, the three-dimensional landscape design has become increasingly prominent, allowing people to place themselves in the digital three-dimensional and experience the unique visual and auditory feelings that virtually brings to people. Literature [19] shows the realistic animation of urban outlook landscape, which can intuitively reflect the development process of the city, make the performance of urban context and image more prominent, and show people's life forms in the city. Literature [20] shows that the three elements of space, path, and visual threshold give full play to the interaction and show multimeaning space. Its organizational mode causes overall environmental participants to increase their autonomous activities, improve their sense of self-satisfaction, provide positive feedback to the environment, affect the interactive experience between the environment and participants once more, and effectively realize interactive media interaction and communication. The combination of various formats, complementary interests among formats, close relationship with cities, and other characteristics of urban complexes are mentioned in literature [21]. Many factors contribute to the operation's success. Although external open space landscape design is one of them, its function is indispensable. The rules of urban design may be reversed, interrupted, or even abandoned for different people under different circumstances. It examines the city's construction from a different perspective, and it also aids my search for a new learning angle in this topic's research. The construction of a virtual city landscape, the use of three-dimensional landscape intersection, and the method of three-dimensional landscape modeling are all examined in this paper.

3. Methodology

3.1. Virtual City Landscape Construction. For a large-scale complex scene, the establishment and optimization of the model are extremely important. Interactivity and realization intention need to be considered. Compared with animation model, there are usually fewer details to improve the real-time effect. On the existing basis, people can only sacrifice the perfect and accurate visual art, achieve a higher level of realism through the balance with real time, and construct a virtual environment that can realistically simulate the real world [22]. With the rapid development of software technology, the computing speed of microcomputer exceeds one billion times. The new technology of computer graphics display card greatly accelerates the computing and processing of landscape data and makes the visual development system of landscape reach a new level of rapid interaction. Three-dimensional landscape visualization equipment has also been greatly developed, and a large amount of production is also slowly carried out. The development of software has mushroomed, and a series of 3D landscape visualization software has been developed [23].

Natural topography and human landscape are included in three-dimensional landscape, which includes complex three-dimensional topography, simple matchbox-shaped houses with regular shapes, trees, waters, and even moving cars and pedestrians, among other things. The foundation of the entire virtual scene and one of the most important research fields in the virtual geographical environment is urban landscape modeling. For a long time, computer scientists have been attempting to replicate a real three-dimensional scene in the real world in the computer [24]. Computers can now draw various complex and realistic 3D scenes in real time, thanks to advances in 3D visualization technology, virtual reality, and real-time realistic graphics, and this ideal is becoming a reality. Drawing based on graphics or geometry, which is actually the simulation of the light interaction process of objects in real scenes, is the traditional method of 3D representation of real objects. The brightness of each visible point on the screen is calculated by the drawing algorithm. Figure 1 depicts the procedure.

People have an insatiable desire for city life in order to survive and develop in the city and to live better in the city. Currently, the urban commercial complex has established itself as a significant commercial center of the city, gradually replacing the previous single architectural model by appearing in the form of a building complex, combining the contents of urban living spaces such as office, business, and residence in the city, and establishing a dynamic relationship of mutual benefit and interdependence on this basis. We can establish an object behavior model independent of user input, in addition to mathematical modeling of the direct response of object motion and physical characteristics to user behavior, as the embodiment of virtual reality's autonomy. The research of a new generation of modeling methods represented by behavior modeling is on the rise, and its application prospects are very promising [25]. With the continued development of virtual reality technology and the expansion of the application field of virtual reality technology, the research of a new generation of modeling methods represented by behavior modeling is on the rise, and its application prospects are very impressive. Determine the spatial position and geometric shape of each building object using the urban basic geographic information database, then get its basic three-dimensional shape using height information, and then map according to the texture of each facade to get the building's basic model.

The building viewpoint data model mainly applies the storage method of point data in vector data; that is, the coordinate points of the building are stored. The attribute data model in the system can be designed into several attribute information tables by applying the design principle of general relational database. The object hierarchy in the vector data model is shown in Figure 2.

The modeling environment provides interactive, multidisplay, and user-defined 3D graphic viewer and a two-dimensional hierarchical structure diagram. All the displays are interactive and fully related, and this flexible combination accelerates the organization of database, model generation, modification and editing, and the definition of structural relationship. In general, there are two types of virtual scene model object representation, specifically representing the outline and shape of primitives in the objects, which can save calculation time during generation but requires a lot of time and space to store and access, and specifically representing the outline and shape of primitives in the objects, which can save calculation time during generation but requires a lot of time and space to store and access. It is beneficial to storage in principle, but it must be recalculated each time it is used. When drawing graphics, it switches among these detail models based on the distance of viewpoint or other standards and automatically selects the corresponding display level, allowing the scene's complexity to be changed in real time without affecting the visual effect. However, the primary goal of using examples is to save memory; as a result, the display speed will be accelerated; however, because the geometric position of objects must be obtained through geometric transformation, the amount of calculation required by the system will obviously increase as the number of example objects increases.

3.2. Application of 3D Landscape Intersection in Commercial Building Complex. Landscape visualization emerges when information technology has progressed to a certain point. The three-dimensional landscape has become the main stage as a result of the advancement of electronic technology. Despite the fact that China is late in developing landscape visualization, many advances have been made in recent years, including research and development of 3D technology for urban landscape visualization, interactive operation of 3D scene models, 3D dynamic interactive visualization models, and visualization technology and its application in geological exploration. Communication expresses the superiority of three-dimensional architectural design, and traditional renderings based on artificial modification contain some misleading elements. However, by presenting the real estate to the developer in the form of a 3D animation, the developer can make an accurate assessment of the scheme's characteristics and quality based on personal experience, allowing the developer to select the best strategy, maximize land utilization and construction project development rates, and significantly increase the cost. By displaying large-scale projects with vivid 3D technology, a vivid 3D model can be built, which can meet the requirements of the masses from multiple angles, levels, and directions, and make reasonable distribution for each key point and channel of the building itself, which resonates with people's design ideas [26]. According to the requirements of the planning scheme, various 3D building models are arranged on it, the simulated digital terrain is generated according to the contour lines of the actual terrain, and with the help of 3D animation software, an animated tour path is created, and finally a section of building roaming with the help of 3D software is completed. Later, text description, music background, graphic materials, and so on can be added to it by software, and some simple query functions can also be realized.

We can show the exterior and interior of the building in detail, as well as the surrounding environment, using 3D representation technology, as if we were on the spot. As a result, first, the workload of the building created using 3D representation technology is reduced, and second, people can more easily feel the information they require. Finally, thanks to advances in 3D technology, people can now modify their dissatisfaction at any time and from any location, greatly reducing time and improving quality. Virtual modeling using geometric models is based on computer graphics, which abstracts the real scene and creates a 3D geometric model of a virtual landscape using polygons. After that, texture mapping and control parameter setting takes place. Finally, using software control, real-time rendering and drawing of the visual picture on

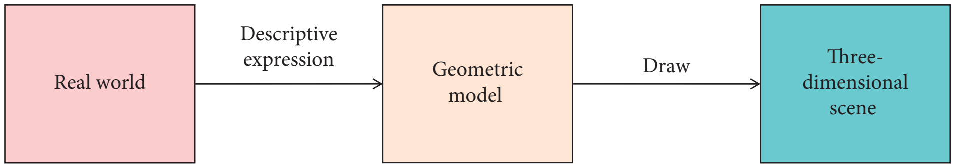

Figure 1: 3D scene construction process.

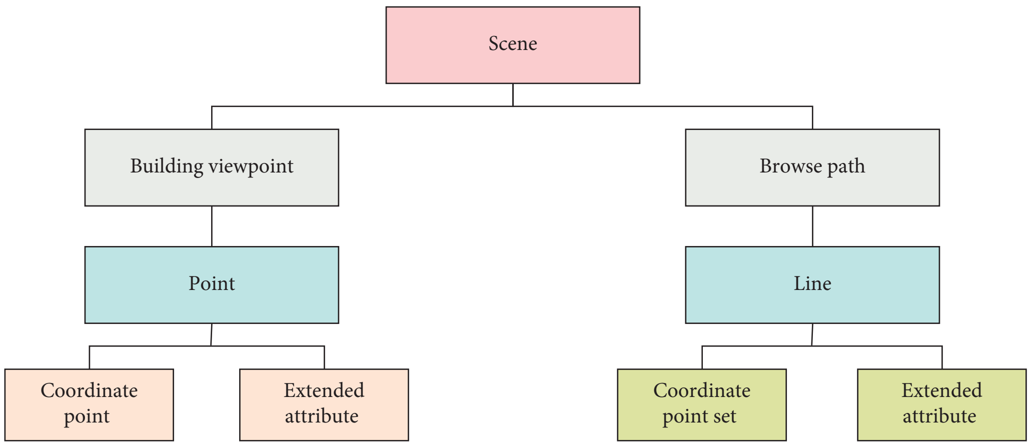

Figure 2: Object hierarchy in the vector data model.

the output device are carried out based on the observer's position, illumination, and blanking information, completing the roaming of the entire scene. Figure 3 depicts the modeling process.

With the appearance of 3D technology, the requirements of computer software and hardware are also improved. The improvement of computer hardware is not difficult, but the improvement of software technology is an arduous task, and there are always unsolvable problems. However, thanks to today's rapid advancements in science and technology, computer software and hardware technology have vastly improved, laying the hardware foundation for 3D landscape intersection technology and expanding its application field. The use of 3D landscape intersection technology in virtual reality, architectural performance, and film and television scenes reflects its importance as a display medium in the field of architecture. It deviates from previous plane renderings' simple plane layouts, combining high-tech animation techniques with gorgeous film and television special effects, vividly and concretely depicting the style of architectural buildings or unique urban buildings, and integrating people's rich life plots, the geographical location of buildings, and the beautiful environment. The rapid growth of China's economy has increased demand for real estate, and the continuous development of urban planning has given architectural animation significant market power. Its outstanding qualities make it a highly sought-after golden occupation field in the twenty-first century.

The relationship between urban status evolution and influencing factors is as follows:

$$Y = F(A, X). \tag{1}$$

Y is the change level of urban state, X is the influencing condition, A is the effect of the influencing condition, and F is the action function. Let us assume that there are n city states that have not been evaluated, the relative change of city states is y, and there are m influencing factors x. Among them, each influencing factor is X, the urban planning factor is x_p, the influence degree of each influencing factor is A, and the influence degree of urban planning factor is a_p. The formula can be expressed as,

$$y_n = f_n\left(a_1, a_2, \ldots, a_p, \ldots, a_m, x_1, x_2, \ldots, x_p, \ldots, x_m\right). \tag{2}$$

Taking into account the spatial and temporal dimensions, this relationship can be expressed as,

$$Y_k^t = F\left(A_k^t, X_k^t\right), \tag{3}$$

where k is the area ID and t is the time period. The area k has the city state $s_k^{t_s}$ at the start time of the time period t and the state $s_k^{t_e}$ at the end time, and then the city state changes $y_k^t = s_k^{t_e} - s_k^{t_s}$ of the area k at the time period t.

The inconvenient expression of architectural language and the designer's poor expression of perspective make it difficult for the masses to communicate and understand the design significance, and traditional architectural expression has significant limitations. We must mention the urban simulation system in the field of urban planning. Its significance lies in the application of virtual reality technology to urban landscape planning and design, with the goal of establishing a real model to reflect the urban environment and then realizing the real model through on-the-spot investigation and data capture into the computer. As a result, using 3D virtual technology and designers' creative ideas, we can fully express a single building, its material color, and our

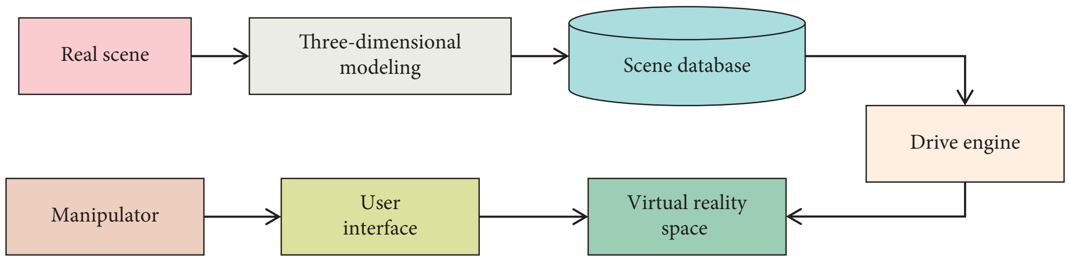

Figure 3: Flowchart of the modeling method.

own cultural information when we want to express all-round architectural information. People require more direct visual expression, and the intersection of three-dimensional landscapes has unquestionably become a necessary tool for people to enjoy the best visual experience. As a result, it is critical to incorporate 3D landscape intersection technology into the user participation design system, as traditional architectural performance is unmatched. It will be more widely used if 3D landscape intersection technology is applied to it.

4. Result Analysis and Discussion

4.1. Three-Dimensional Representation of Urban Landscape Commerce. Through the technical means of three-dimensional animation, artworks that show the vividness, aesthetics, creativity, and emotion of three-dimensional dynamic images from all angles [27]. The prospect of urban three-dimensional commercial performance in practical commercial application is still very broad. With the development of computer technology and technology, there will be more and more mature methods for building urban 3D landscape models, with higher modeling efficiency and better model quality. An important part of the three-dimensional landscape interaction is the three-dimensional animation of urban prospect landscape, which is essentially different from other kinds of animation. It mainly focuses on the prospect of future urban development and teaches intuitive three-dimensional deduction of future cities, showing the expression methods of urban development, urban rhythm, and urban image color. It can intuitively interpret the state of people's lives and the features of the city.

The physical attributes of objects are considered in the modeling of commercial complex. Fractal technology and particle system are typical physical modeling methods. Fractal technology can describe data sets with self-similar characteristics. Figure 4 shows the comparison results of algorithm performance before and after storage optimization.

Cultural Preservation in the City Landscape architecture performance is a form of cultural protection for urban landscapes based on the display of visible and intangible, static, and dynamic virtual reality technology. Today's cities are rapidly developing, but this rapid development has severely weakened the cities' original cultural atmosphere as well as their historical and cultural heritage. We should make a strong appeal to our people to protect our traditional urban culture and historical culture, using urban culture to protect landscape architecture animation, raise societal awareness, and deeply love our own urban history and culture; history is irreversible, so how can we strengthen awareness of inheriting our own history and culture, maximize protection, and make the city where we live have a good cultural atmosphere?

As a new business model, commercial complexes have not been in China for a long time, and there are basically no successful examples in China for reference. In fact, urban commercial landscape is to display the characteristics of the original architectural style in urban commercial complexes from the perspective of landscape designers and, at the same time, make these commercial buildings bring people a warm, comfortable, and relaxed shopping and leisure environment. Commercial landscape design should be combined with urban design, so that the landscape can reflect the humanistic and three-dimensional characteristics and better integrate with the city, thus providing important guidance for urban development. Landscape design can humanize the architectural space, at the same time, increase more added value of fine products, and also have a great impact on the lifestyle of residents. On the whole, the construction of business environment has certain forward-looking characteristics. Landscape ecology places special emphasis on maintaining and restoring the continuity and integrity of landscape ecological process and pattern, that is to say, maintaining the spatial relationship between residual green patches in cities and natural patches in wetlands.

The commercial building complex model created based on the task of three-dimensional landscape interaction can solve the possible design problems and quality problems of the project in advance through collision detection and other forms. Figure 5 shows the comparison of simulation of commercial building topology reliability optimization before and after optimization.

Three-dimensional landscape interaction measurement relationship is also widely used in planning results in the area statistics of planning land, the calculation of floor area ratio of different land types, the height and density of buildings, and the minimum distance between buildings with different heights. The approximate relationship between road width and building area is shown in Figure 6.

As a public place to provide consumption and leisure for urban residents, the landscape design of urban complex must strictly follow the principle of publicity. To a great extent, it has replaced urban public spaces such as city

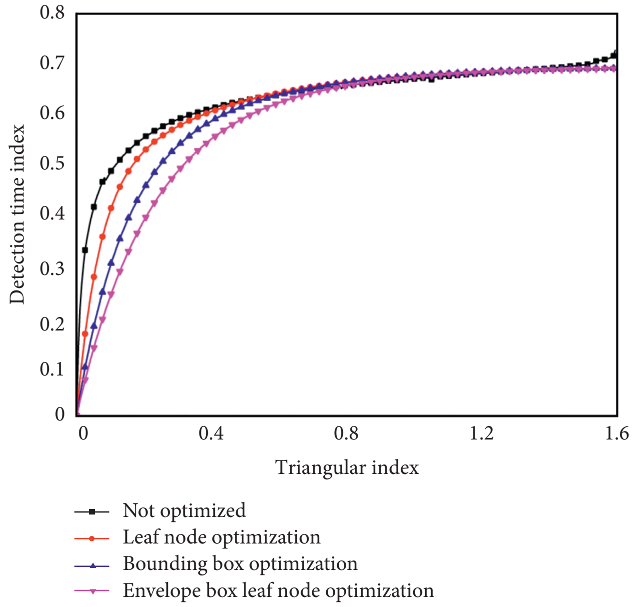

Figure 4: Comparison of algorithm performance before and after storage optimization.

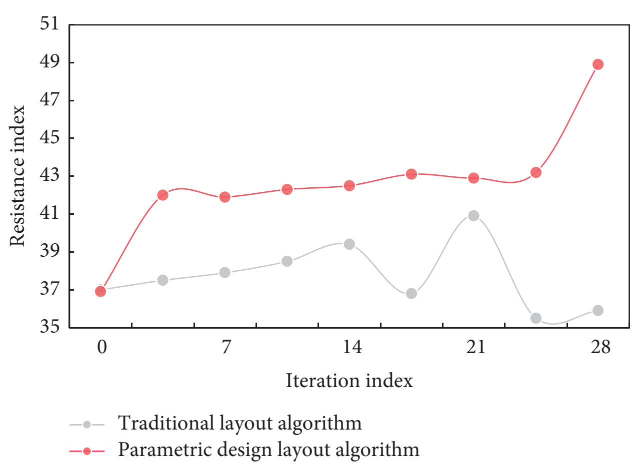

Figure 5: Simulation comparison of commercial building layout optimization.

streets and squares, and now urban commercial complexes have evolved into a main carrier of urban public activities. In the commercial landscape design of urban complex, the whole city should be regarded as a whole, and the construction should be based on it. In this case, the boundary between the city and the building becomes increasingly blurred. At the same time, designers should pay full attention to local historical and cultural traditions and pay attention to issues such as national personality, cultural customs, and religious beliefs, so as to show local characteristics by using various expression techniques in the design process.

4.2. Analysis of Building Characteristics. The method of building model includes the plane data and height data of the building. With the development of computer technology

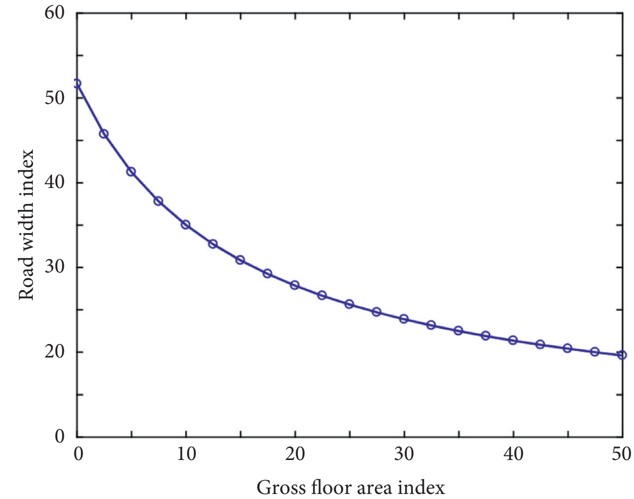

Figure 6: Relationship between road width and building area.

and graphics technology, some modeling software can be used to achieve finer and finer modeling to meet the basic visualization requirements into the three-dimensional modeling software and then directly stretch to the corresponding height to get the basic external surface model of the building. Through texture mapping, a complete building model can be obtained. Geometric modeling is the first development in the three-dimensional landscape interaction of commercial building complex layout. Analyze its path density, number of nodes, and central potential. The relationship between path density and node path is shown in Figure 7.

In terms of function, the close overlap between necessary space and auxiliary space improves the utilization rate of commercial landscape space and the vitality of space, thus strengthening space communication and strengthening commercial functional space. In terms of form, polysemy space revolves around the theme of complex landscape, and multidirectional guiding space is used in landscape nodes such as scenic spot transformation, so as to transform the space into nature, coordinate and strengthen the landscape theme as a whole, and promote the accessibility of the theme. Following the characteristics of people's public activities, the route layout considers the various route requirements of various formats in commercial complexes, and vertical traffic such as inevitable routes, horizontal passages, and landscape continuous routes is organized in a network to ensure high accessibility of major activity areas. Building texture is an important part of the 3D landscape. The majority of texture data comes from field photographs and is directly related to 3D scenes. As a result, texture data quality determines whether a more realistic expression effect can be achieved. Roads and their appendages, vegetation, the water system, independent features, and so on are examples of surface appendages. The 3D expression of plants such as flowers, trees, and other objects is an important part of the 3D landscape during the construction of the entire city 3D landscape, and it is also directly related to the fidelity of the 3D landscape expression.

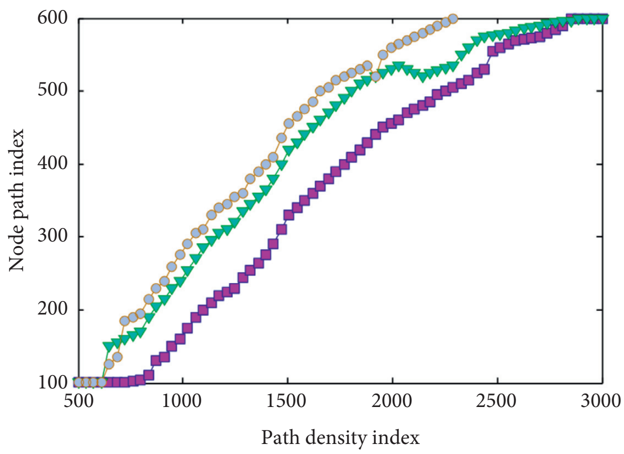

Figure 7: Path density and node path relationship.

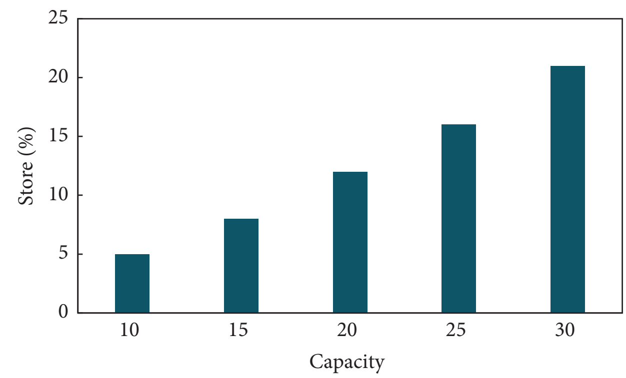

Figure 8: Excess cost ratio of single domain strategy.

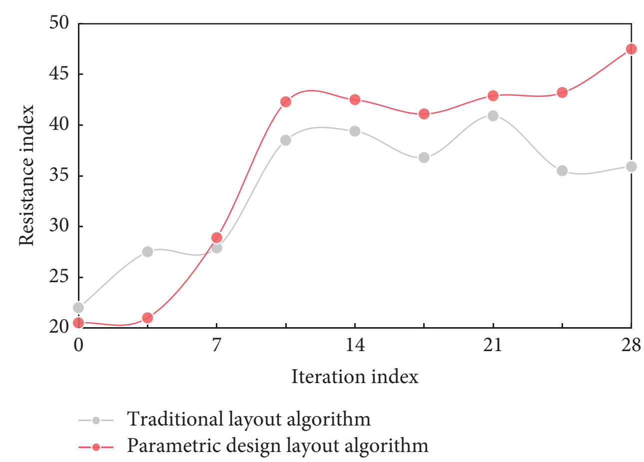

Figure 9: Simulation comparison.

The top texture of 3D building model cannot be directly obtained by field photography, so it can only be collected from orthographic images with original resolution, which can reduce workload and difficulty, and at the same time ensure the quality of texture data. Assume that the capacity of intradomain links is the capacity of interdomain links. The performance is illustrated by three different scenarios, as shown in Figure 8.

Fully consider the psychological factors of the active crowd, follow the changes of space and path, set the viewpoint, consider the attraction and guidance of the crowd's sight within the scope of sight, and consider the intensity and density of the sight direction and each attraction point within the visual threshold scale when arranging the landscape nodes. From the viewpoint, according to the sight demand of the active crowd, the scenic spots with different intensities and spaciousness are displayed in different sight scales, such as intimacy scale, etiquette scale, and public scale, so as to influence the diversified choices of user paths and make the experience interaction between each scenic spot and users. The simulation comparison of topology stability optimization is shown in Figure 9.

From the beginning of people's participation in the landscape experience, they have been actively or passively playing the role of interactive experiencer in the landscape, and their interaction mode is mainly direct expression, that is, active and direct participation in the landscape. Usually, when the landscape is represented by objective substances such as visual images, people tend to get close to nature actively and make automatic choices based on physiological reactions. The typicality of scenic spots and synaptic settings are the direct choice of human-landscape interaction. Effective arrangement of facilities and landscape nodes play a leading role in people's sense of participation and experience. Second, when the overall artistic conception of the environment is coordinated with the theme, the crowd's freedom will change the way they experience the world with the change of the path, be attracted by sound and shadow, be attracted by the gathered crowd, be attracted by unexpected events that have not been planned, and so on, all of which will have an impact on the interactive subject. The study of the interaction of commercial complexes and 3D landscape design can help to boost the economic benefits and vitality of urban commercial areas, as well as promoting the organic coexistence and development of people and the urban commercial landscape.

5. Conclusions

The development of history and civilization is not fast, and it will not have a long span, due to the city's constant expansion and construction. In general, once a city has reached a certain level of development, it is relatively stable. Modern cities have a large population, a large scale, and a complex functional structure, making commercial building complexes difficult to define and shape. This paper systematically examines related theories and methods in the construction of virtual cities, with a focus on comprehensive virtual city modeling, three-dimensional visual browsing and query, and so on. It has quickly spread throughout the city as a dynamic factor that can best promote urban economic development due to its development mode of maximizing land use. It is difficult for a single commercial structure to become a business gathering place. As a result, the commercial building complex has become an advantageous commercial carrier, allowing for increased attention to outdoor open space landscape design. The external space of an urban complex is systematically planned using modern landscape design knowledge, creating a landscape environment with intensive functions, high identification, and reasonable spatial combination, and jointly acting on a region to bring economic benefits. With the rapid advancement of science and technology, we must not only preserve our cultural heritage, but also begin to learn and receive new knowledge, as well as arming ourselves with new science and technology, in order to construct a better city and achieve faster development.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

A Novel Data Visualization Model Based on Autoencoder Using Big Data Analysis and Distributed Processing Technology

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From the standpoint of visual elements, this article investigates the use of visual information technology in visual communication design. At this time, information visualization and data visualization are widely used to display visual form, which greatly facilitates people's use, provides a solid application foundation for visual communication design, and promotes its development. The image presentation of data is a common encoding process, and the reading of image content is the corresponding decoding process from the perspective of encoding and decoding. The combined efficacy of data encoding and image decoding determines the effectiveness of data visualization. It is worth noting that when it comes to "encoding and decoding," it has been established that the design mode of data visualization and visual communication is not a process of copying images but rather an external form of human thought. Then, there is the unmistakable presence of something unseen in the encoding and decoding processes. It also serves as the encoding and decoding key in the human brain. The image is as follows. From the standpoint of encoding and decoding, this article employs the data visualization self-encoder method to obtain visual data. Design pattern representation for perceptual communication can effectively support users' rapid motion analysis during the browsing process.

1. Introduction

The torrent of data conversion will become a trend as we move from Industry 4.0 to Industrial Internet and then to intelligent production. People are finding it more and more convenient to obtain information and data thanks to the rapid development of the Internet. Massive data quickly became a source of concern for the general public and the rate at which massive data were generated increased. This is a clear and beautiful topic in the field of visual communication [1]. Without a doubt, with the rapid advancement of technology, visual communication design will no longer be limited to a few well-known categories but will also include more related majors and make use of new science and technology to achieve a new level of separation. People's cognitive load can be reduced and a clear and intuitive visual expression can be formed using data visualization and graphical interface in an organic way [2]. Since the invention of cameras, televisions, and other tools, visual communication design has been in the process of image transformation, and interface design, as a subset of visual communication design, has also been in the process of image transformation. Vision has a significant impact on viewing data [3]. This article analyzes the application of visual information technology in visual communication design from the perspective of visual elements. At present, the display of visual form by information visualization and data visualization has been well applied, which greatly facilitates people's use, provides a certain application foundation for visual communication design, and promotes the development of visual communication design [4].

In this game, it is not a small step forward for human beings to consciously explore the rules and skills of coding from an unconscious coding, and it is also an aspect of human evolution without exaggeration. It is worth noting that when it comes to "encoding and decoding," it is affirmed that visual communication design is not a process of copying images but an external manifestation of human thought, so there is no doubt that there is something invisible in the human brain in the process of encoding and decoding, which is also the key to encoding and decoding. That is images [5, 6]. From the point of view of coding and decoding, the image presentation of data is a typical coding process, and the reading of the image content is a corresponding decoding process. The effectiveness of data visualization is the unity of the effectiveness of data coding and the effectiveness of image decoding [7, 8]. Coding shows the maximum amount of information in the shortest time and the least space, and the choice of a visualization method is very important [9, 10]. Coding and decoding are two different things. Data information can reduce the interference of a large number of visual noises in the process of visual coding with the help of the correct visualization method, which can lead to different mining attributes of data from many angles and discovering the important information hidden in the data [11]. The real position of the current voxel in the two code tables is determined using the two-layer code table index and the corresponding offset address, and the two texture coordinates are then used to obtain the decoded value in the corresponding code table. The reconstructed data value of the voxel is obtained by adding the two decoded values and the mean value [12, 13]. To determine the importance of data visualization in visual communication design patterns and make similar data adjacent to each other, data visualization and visual communication design patterns are coded [14].

Visual communication design under the coding and decoding theory can only take the road of diversified development, strengthen its own design, and differentiate development to participate in market competition. On this basis, it continuously interacts with, integrates, and continuously realizes innovation and improvement [15]. From the point of view of coding and decoding, the image presentation of data is a typical coding process, and the reading of the content in the image is a corresponding decoding process. The effectiveness of data visualization is the unity of the effectiveness of data coding and the effectiveness of image decoding. Simultaneously, it cultivates their desire to seek out differences, greatly improves their level of appreciation, aesthetic ability, and innovation ability, and lays the groundwork for cultivating skilled professional talents and innovative talents. To obtain the visual communication design pattern representation, a data visual self-encoder method based on the perspective of encoding and decoding is proposed, which can effectively support the rapid motion analysis of users in the browsing process. The proposed method's effectiveness is confirmed by the experimental results on the visual communication design pattern dataset.

2. Related Work

Literature [16] pointed out that a method of data visualization browsing uses KMeans to iteratively turn the visual communication design pattern in the data visualization set into a hierarchical tree and studies the data by specifying the starting and ending visual communication design patterns. In literature [17], using the big data analysis method and qualitative analysis of quadruple and maximum segmentation method, the visual communication design pattern is transformed into a systematic evolutionary tree, and better results of visual communication design pattern construction are obtained. Research in literature [18] showed that compared with tree organization, the visualization method of visual communication design pattern of scatter diagram based on SOM does not need to transform the relationship between nodes into a one-to-many parent-child structure. Literature [19] pointed out that the acquisition method of visual communication design pattern was introduced, and the application of data visualization in visual communication design was summarized. At the same time, the research approach of data visualization was discussed. In literature [3], through the big data analysis method, from the behavior angle of visual communication design pattern, based on the analysis method of data visualization, the characteristics of visual communication design pattern were studied, and the regularity of visual communication design pattern was excavated. Finally, the scope and demand situation of visual communication design patterns were studied. Literature [20] showed that users can finally get the desired visualization of target data by browsing. Compared with the retrieval method of example query, this method does not require users to provide query examples but also provides an important interface for users who are uncertain about the retrieval target or unfamiliar with the data field. Literature [21] pointed out that data visualization and related data are used to extract the amount of data in the process of design mode, which is used to predict the application of future visual communication design mode in data visualization and predict and analyze the visual communication design mode according to the amount of data. Literature [22] organized the analysis methods and ideas of visual communication design patterns from an application perspective using the big data analysis method, built the framework of a data visual listening system, explained the goals of data mining from the two perspectives of data and design, and explained the analysis process and mining methods of visual communication design patterns. According to literature [23], relevant methods for analyzing and studying visual communication design patterns are proposed after in-depth mining and analysis of data visualization, which aids in developing visual communication design patterns. According to literature [24], after analyzing the data of visual communication design mode, some methods for calculating the operation index of visual communication design mode are given based on data visualization. From the standpoint of encoding and decoding, this article investigates the design pattern of data visualization and visual communication. The image presentation of data is a typical coding process, and the reading of the image content is a corresponding decoding process in terms of coding and decoding. The combined effectiveness of data coding and image decoding determines the effectiveness of data visualization and visual communication design patterns.

3. Algorithm and Principle of Encoding and Decoding

The coding and decoding processes are asymmetric, and the propagation process is a circular circle rather than a line, with multiple interconnected but distinct links. Visual design and information transmission are the corresponding coding and decoding processes in the field of data images. Designers imbue images with inherent and intrinsic meanings. Although the decoding of data images based on images and visuality gives the impression that "seeing is believing," it leads to the delusion that image symbols are equivalent to real-world objects. The audio signal is first passed through an analysis subband filter bank, which is the first step in coding. With a reasonable time and frequency decomposition rate, the filter bank divides the input signal into 32 equidistant frequency subbands and extracts the subband sampling signal with a factor of 1/32. The extracted result from whole subband sampling is equivalent to the source signal, but there is some distortion. In a frame, there are 152 PCM audio samples, so each subband has 36 samples. The filter bank's output is calculated using the following equation:

$$St[i] = \sum_{k=0}^{63}\sum_{j=0}^{7} M[i][k] * (C[k+64j] * x[k+64j]), \tag{1}$$

where $St[i]$ is the sampling output of subband I at time t, $C[n]$ is the coefficient of 512-point analysis window defined in the standard, and $x[n]$ is the audio sampling input read from a 512-point sampling buffer. However, $M[i][k] = \cos[(2*i+1)*(k-16)*\pi/64]$ is the coefficient of the analysis matrix.

The above formula is transformed into an easy to understand convolution form to facilitate analysis:

$$St[i] = \sum_{n=0}^{511} x[t-n] * Hi[n], \tag{2}$$

where $x[t]$ is the audio sample $Hi[n] = h[n] * \mathrm{Cost}[(2*i+1)*(n-16)*\pi/64]$ at time t, and $h[n] = -C[n]$, when the integer part of $n/64$ is odd. $= C[n]$, when the integer part of $n/64$ is even; n is from 0 to 511.

In order to adapt to this change, the training sample set is updated by adding new samples and excluding old samples. A reasonable time interval T is selected. At time t, there is XR = XT... X (T-T). When new samples arrive, the training set has to be updated χ $T$and reestimate $\hat{p}(\vec{x}|XT, BG+FG)$. However, some values from old samples may belong to foreground objects, so we should use $p(\vec{x}^{\,t}, BG+FG)$ estimation to use GMM with m components. The corresponding formula is as follows:

$$p(\vec{x}^{\,t}|\mathrm{XT}, \mathrm{BG}+\mathrm{FG}) = \sum_{m=1}^{M} \hat{\pi}_m N\left(\vec{x}, \vec{\mu}, \hat{\sigma}_m^2 I\right), \tag{3}$$

where $\vec{\mu}_1 \ldots \vec{\mu}_M$ represents the average value estimated by the encoding and decoding component; $\vec{\sigma}_1 \ldots \vec{\sigma}_M$ represents the variance estimated by the encoding and decoding component; the covariance matrix is assumed as the diagonal unit matrix I; the weight is expressed by $\hat{\pi}_m$, and it is nonnegative and the sum of the weights is 1. Given a new sample at time t, the encoding and decoding model is updated using the following formula:

$$\begin{aligned}
\hat{\pi}_m &\longleftarrow \hat{\pi}_m + \alpha\left(o_m^{(t)} - \hat{\pi}_m\right),\\
\vec{\mu}_m &\longleftarrow \vec{\mu}_m + o_m^{(t)}\left(\frac{\alpha}{\hat{\pi}_m}\right)\vec{\delta}_m,\\
\hat{\sigma}_m^2 &\longleftarrow \hat{\sigma}_m^2 + o_m^{(t)}\left(\frac{\alpha}{\hat{\pi}_m}\right)\left(\vec{\delta}_m^{\,T}\vec{\delta}_m - \hat{\sigma}_m^2\right).
\end{aligned} \tag{4}$$

Usually, the invaded objects are represented by some clusters with a small weight, so the first B largest clusters are used to approximate the background model:

$$p(\vec{x}^{\,t}|XT, BG) \sum_{m=1}^{B} \hat{\pi} mN\left(\vec{x}, \vec{\mu}_m, \hat{\sigma}_m^2 I\right). \tag{5}$$

If the components corresponding to each pixel are arranged in descending order of weight, you can get

$$B = \mathrm{argmax}_b\left(\sum_{m=1}^{M} \hat{\pi}_m\left(1-c_f\right)\right), \tag{6}$$

where CF represents a maximum scale value that belongs to the foreground object but does not interfere with the background model. For example, if a new object enters the scene and remains stationary in the scene for a period of time, the object is likely to generate an additional stable cluster. Due to the occlusion of the background, the weight π_{B+1} of the additional cluster will continue to increase. If the object remains stationary for a long enough time, the corresponding weight will slowly exceed CF and it will be regarded as the background.

Given data x_1: T, x_i is the ith, t is the total number of data contained, and its corresponding hidden state is Z_1: t. In this article, z_i is the projection coordinate on the two-dimensional plane. Assuming the positive and negative directions, the conditional probability distribution of z_t about X can be expressed as $P(z_t|x_{1:t}, x_{t:T})$, where x_1:T is the time positive direction and X_t:T is the time reverse direction. According to VAE theory, we need to find a distribution $Q(z_t|x_{1:t}, x_{t:T})$ to approach cc by KL divergence $P(z_t|x_{1:t}, x_{t:T})$, and KL divergence is defined as q and p:

$$\begin{aligned}
D_{KL}(P,Q) = &\int Q(z_t|x_{1:t}, x_{t:T})\log\frac{Q(z_t|x_{1:t}, x_{t:T})}{P(z_t|x_{1:t}, x_{t:T})}dz_t\\
&+ D_{KL}(Q\|P(z_t)) - E_{zt\sim Q}\log P(x_t|z_t, x_{1:t-1}, x_{t+1:T}).
\end{aligned} \tag{7}$$

If the first term of equation (7) is a fixed term, minimize D and (P, q) can be transformed into maximization:

$$D_{KL}(P,D) = -D_{KL}(Q\|P(z_t)) + E_{zt\sim Q}\log P(x_t|z_t, x_{1:t-1}, x_{t+1:T}). \tag{8}$$

Equation (8) is also called the variational lower bound. Suppose that $P(z_t)$ obeys the distribution of $N(z_t{:}0,I)$ and $Q(z_t|x_{1:t}, x_{t:T})$ obeys the distribution of $N(z_t; \mu_t, \sigma_t)$, where $\mu_t = f_{\text{enc}}(x_t), \sigma_t = g_{\text{enc}}(x_t)$; then, $-D_{KL}(Q\|P(z_t))$ in formula (4) is

$$-D_{KL}(Q\|P(z_t)) = \frac{1}{2}\sum_{j=1}^{J}\left[1 + \log\left(\sigma_t^i\right)^2 - \left(\mu_t^j\right)^2 - \left(\sigma_t^j\right)^2\right]. \quad (9)$$

Equation (7) can be calculated by sampling from $Q(z_t|x_{1:t}, x_{t:T})$, z_t^l is the implicit vector of sampling, and the second term can be approximately as follows:

$$\begin{aligned} &E_{z_r \sim Q}\log P(x_i|z_r, x_{tz-1}, x_{l+1r}) \\ &\approx -\frac{1}{L}\sum_{j=1}^{L}\left\|x_t - h_{\text{dec}}\left(z_t^l, x_{1:t-1}, x_{t+1:T}\right)^2\right\| + c. \end{aligned} \quad (10)$$

According to the above analysis, the variational lower bound of equation (7) can be expressed by equations (8) and (9). In this article, fenc and genc are coding functions, and hdec are decoding functions, which are similar to those in the BiLSTM neural network. The network structure of the decoding algorithm is shown in the figure.

In order to better adapt to the change of environment, replace equation (4) with equation (6), and the updated formula of weight can be obtained as follows:

$$\hat{\pi}_m \longleftarrow \hat{\pi} + \alpha\left(o_m^{(t)} - \hat{\pi}_m\right) - \alpha c T. \quad (11)$$

Among them, $c\ T = c/T$, c corresponds to the number of samples supporting a Gaussian component; for example, $\alpha = 1/T$ can be selected, then at least $c = 0.01 * T$ samples are needed to support a component, and then $c\ t = 0.01$ can be obtained, and the specific flow corresponding to GMM is shown in Figure 1. The network structure diagram of the decoding algorithm is shown in Figure 2.

4. Methodology

4.1. Data Visualization and Visual Communication Design Pattern. The deeper reason for data visualization and visual communication design pattern lies in the mutual separation of "form metallurgy" and "content metallurgy." In the dimension of the visual design of data images, the content is deprived of form by strong governance, and designers have to go to great pains to find the most perfect form. In the dimension of data image content transmission, the audience has to strive to understand the content across the form, and the form realizes the separation of the content in a figurative manner. The development of data visualization and visual communication design pattern has gone through the process from static to dynamic and then to interactive presentation. The improvement of data visualization can obviously slow down the disharmony of visual communication design pattern, but it is still limited by the time period. Interaction in advance and interaction in the event are still needed; that is, analysis of the audience in advance and strengthening emotional communication in the event are needed. In order to verify the effectiveness of the coding and decoding model and algorithm, we first use the data visualization in the benchmark scene to train and test the model of our visual communication design pattern, compare the performance of network models at different depths, and compare it with the original GMM algorithm and the current advanced algorithm. Then, we further fine-tune and test the visual communication design pattern model in some new scenes. From the perspective of encoding and decoding, designers need to "design rationally"; specifically, based on data visualization, set design according to the purpose, highlight visual communication of design pattern information, match it with secondary information, and then present it aesthetically. "Reasonable" design is based on the fact that the visual communication design mode has at least the general level of image design ability. The "image garbage" and "image mediocrity" caused by "over-smelting" and "under-smelting" are not desirable. It should be noted that "reasonable" design does not require high data density image design or other high-level design, but it does not exclude the design for specific objects and specific purposes. Because there are many data visualization information and complex relationships, directly visualizing all data will lead to bloated graphics and difficulty of reading; simplifying data visualization will affect the completion of information performance, integrity, and accuracy. In the face of specific requirements, or focus on visual design, or focus on content communication and purpose, data visualization and visual communication design patterns can be finely designed to achieve specific effects. At the same time, based on the diversified needs of data visualization, visual communication design patterns can also be designed for specific data or nonspecific data. Firstly, this part analyzes the steps of data visualization and visual communication design pattern coding, which is described based on diagrams. Firstly, the input data visualization is based on a visual communication design pattern that divides the input signal into 32 equidistant frequency subbands. The sampled signal after this process is still in the time domain. Then, the sampled signal is mapped to the frequency domain by an improved discrete cosine transform. At the same time, the input PCM signal is transformed by FFT and then passed through a psychoacoustic model to judge the signal mask ratio of each subband, as shown in Figure 3.

The design pattern of data visualization and visual communication is a process of graphic simplification, which is a requirement for designers, and the information reading of data images is a complicated process, which is a requirement for audiences. Only when the requirements are clear can the problems to be solved be clearly defined and the design have an accurate direction. In the design mode of visual communication, many methods are widely used to analyze data visualization, such as interviews with users, situational investigation, auxiliary understanding of virtual objects' roles, and organizing targeted discussions among users. Referring to the training process of segnet, both models use the cross-entropy function as the loss function and use the random gradient descent algorithm to train on the Caffe framework. When training subnet-4, the

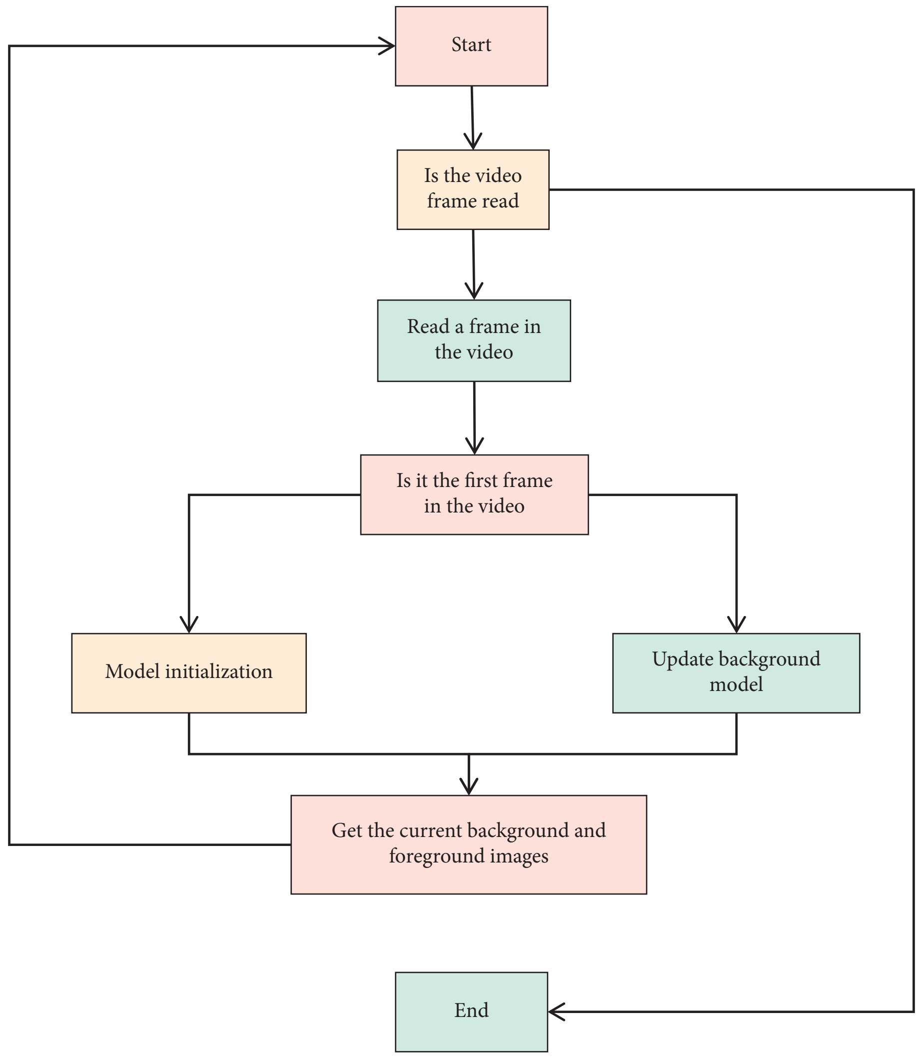

Figure 1: Flowchart of encoding and decoding model.

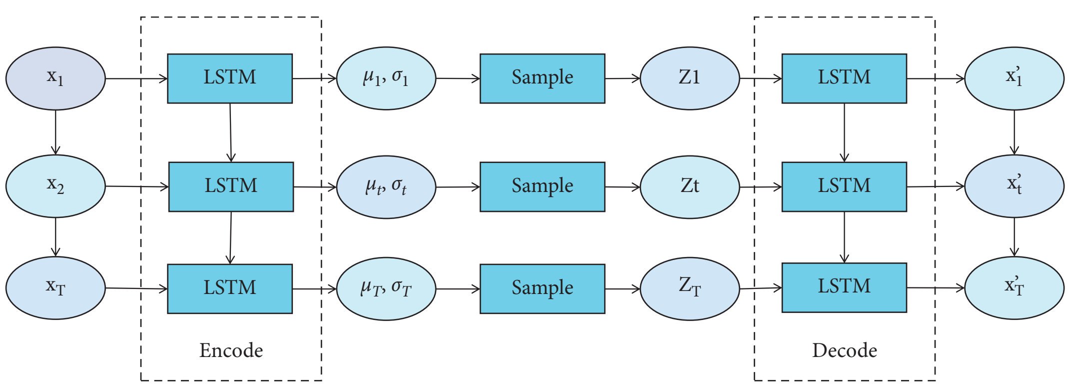

Figure 2: Network structure diagram of encoding and decoding algorithm.

learning rate is fixed at 0.01 and the batch size is set to 10 according to the actual hardware conditions; when training subnet-13, the learning rate is fixed to 0.001 and the batch size is set to 4. We observed that after about 15 training cycles (epoch, which means that all training data are trained once), the two visual communication design pattern models have basically converged. In order to compare the performance of models with different depths, we further trained the two visual communication design pattern models to about 30 cycles and then tested them on the resulting visual communication design pattern model. The visual change process of loss data during the training of two visual communication design pattern models is shown in Figure 4.

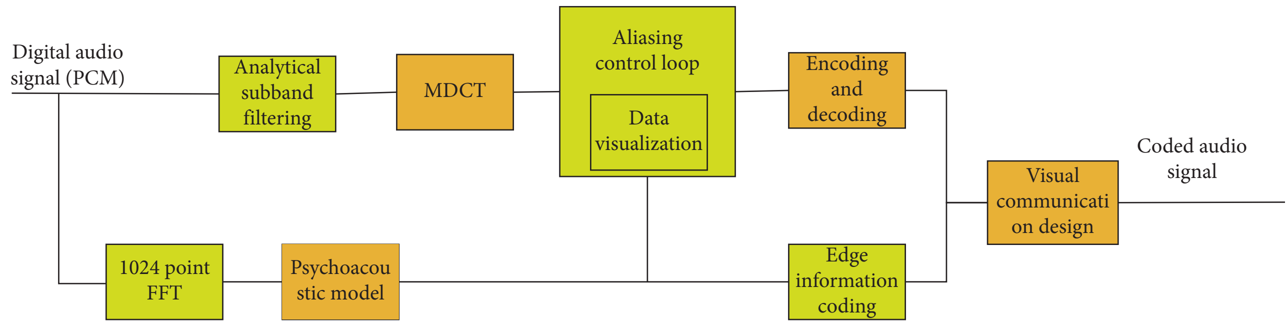

Figure 3: Block diagram of data visualization and visual communication design pattern coding.

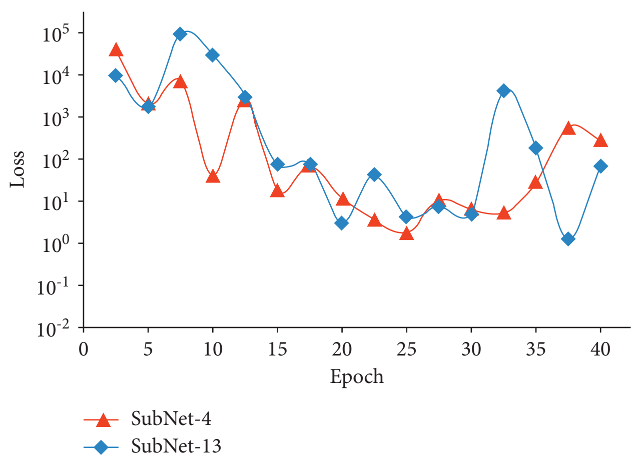

Figure 4: Numerical change curve of data visualization in visual communication design mode during training.

4.2. Experimental Results of Encoding and Decoding Algorithm in Data Visualization and Visual Communication Design Pattern. The coding and decoding algorithm performs similarly to the current top algorithms, and this is achieved without further optimization of the background modeling algorithm or the detection results (for example, DeepBS uses time median filtering to further process the results after obtaining the detection results), demonstrating that the coding and decoding algorithm is very competitive and has a lot of room for improvement. The advantages of data visualization and visual communication design patterns can complement and confirm each other by commenting on them or linking to the text content library. The look-up table simultaneously inputs the value of code length into an accumulator after a codeword is decoded. The accumulator serves two purposes: first, it indicates the position of the next word to be decoded in the buffer, which is calculated by adding the lengths of previous codewords; second, once all codewords have been decoded, the buffer is notified that new codewords are available from the bitstream. The look-up table's structure is made up of data pointers and memory, with the Huffman code table to be used in decoding already stored in memory. Because the encoding and decoding algorithm includes both Huffman encoding and scale factor in the main data, it can be assumed that a single-state machine can perform both Huffman and scale factor decoding at the same time. This can simplify the design code and save the hardware area, which can be realized by sharing the master data register by Huffman decoding and scale factor decoding. "We should be moderately skeptical about the reliability of the following information, cooperate with the data collection and processing personnel to check its authenticity, and then use it as the basis for making the data visualization and visual communication design mode." Regardless of the length of the codeword, the clock cycle required for decoding each codeword is the same, and the decoding time is relatively short, which is more suitable for requiring real-time decoding. Moreover, when Hoffman's code table changes, it only needs to modify the data in the look-up table, which is more convenient in terms of universality. In the interaction between data visualization and visual communication design mode, the designer has greater control because they are the supplier of image products. "The audience has no way of verifying himself." Whether or not data visualization is the source data information: first and foremost, it is not required. The image must be self-evident but separated from the visual communication design mode results in the loss of the reference object during verification; second, data visualization implies the conception and trade-off of the visual communication design mode, and restoring the source information is thought to be denying the designer's work and the value of the information map; third, it is a goal of data visualization; fourth, it is a goal of data visualization. The second goal is to encourage in-depth thinking and sublimation. We do not want the thinking to get stuck in the tangle of visual communication design mode after "understanding." The audience, on the other hand, is not taken for granted. The audience has the ability to read and understand basic judgments of image superiority and inferiority and the ability to "vote with their eyes"; that is, pay less attention to or ignore poorly designed data images. We conducted experiments and tests on other scenes of the CDnet dataset to further verify the generalization ability of the data visualization and visual communication design pattern model from the perspective of encoding and decoding. We only used subnet-4 to conduct related experiments here, based on the results of previous comparisons of different depth encoding and decoding networks. The performance of subnet-4 and subnet-13 is examined in each scene of data visualization, as shown in Figures 5 and 6.

We find that the algorithm performs well in the highway scenario but poorly in the office and pedestrian scenarios. Information transmission is realized through the encoding and decoding algorithm. There is no need to investigate

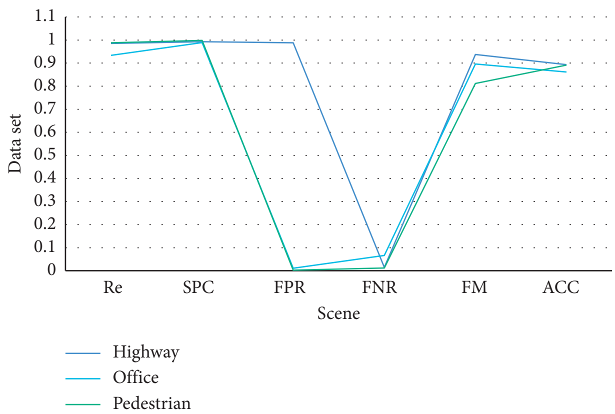

FIGURE 5: Performance of subnet-4 in various scenarios of data visualization.

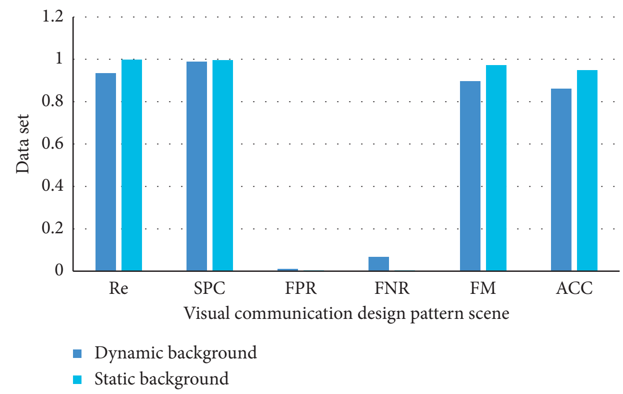

FIGURE 7: Performance of encoding and decoding in data visualization and visual communication design mode scenarios under different backgrounds.

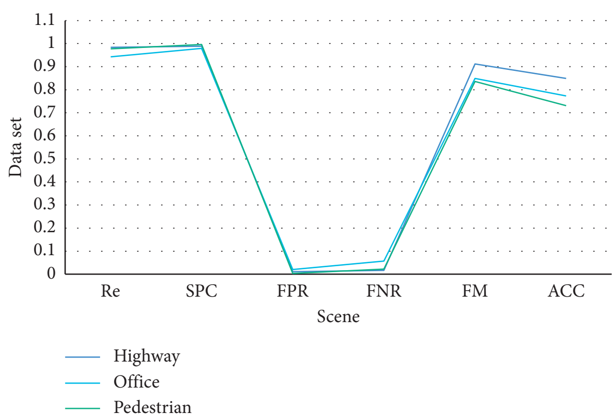

FIGURE 6: The performance of subnet-13 in various scenes in data visualization.

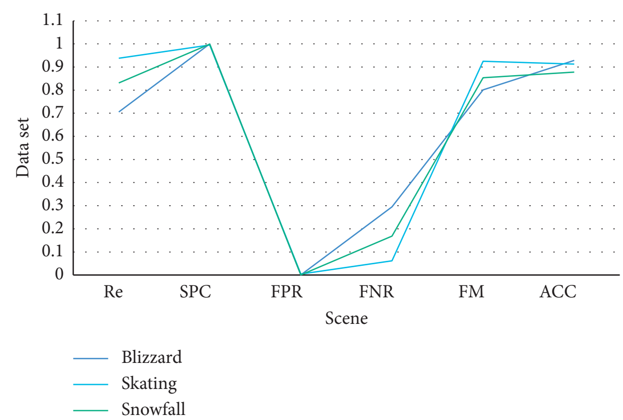

FIGURE 8: Performance of encoding and decoding algorithm in different scenarios of data visualization.

defects in the design process of data visualization. As long as the local visual communication design does not affect the beauty of the whole image and the audience can still understand the meaning of the image by bypassing defects, it is understandable. Of course, obvious errors are not allowed, which is related to the designer's own reasonable duty of care, including data visualization and visual communication design pattern comparison review, image ambiguity review, and aesthetic common sense review. The results show that our data visualization and visual communication design patterns are used to find the foreground object through the difference between the background image and the video frame; however, due to the shortcomings of the GMM model itself, the foreground object in the scene of data visualization and visual communication design pattern stays in the scene for a long time, which leads GMM to mistake it for the background. Considering that the design pattern of data visualization and visual communication is a scene with little background change, the subnet-4 model is used for testing, and the test results are shown in Figure 7.

First of all, we used some scenes of subnet-4 trained in data visualization dataset under the category of data visualization and visual communication design pattern dataset badWeather, and the results are shown in Figure 8.

The results show that the encoding and decoding algorithm performs well in skating scenes but not in other scenes due to the interference of fluttering snowflakes in bad weather scenes. We may not get good results based on the contrast between the background and video frames. Using an encoding and decoding algorithm, we can fine-tune and optimize the data visualization and visual communication design pattern. In particular, we randomly selected a portion of the data from the above scenarios, taking 10% of each scenario's data, for a total of about 2000 data, and then trained and fine-tuned subnet-4 for about 30 weeks. We tested the model in these scenarios after it converged. We also tested the average performance of the fine-tuned data visualization and visual communication design pattern model in the highway, office, and pedestrians scenes in the CDnet2014baseline category to see how fine-tuning affected the model. Figures 9 and 10 depict the test results.

It is clear from the results that the fine-tuning data visualization and visual communication design pattern model's performance in the new scene has vastly improved over the original model and that the average performance in the badWeather scene even outperforms the best existing algorithm. One of the more intriguing findings is that the fine-tuned data visualization and visual communication

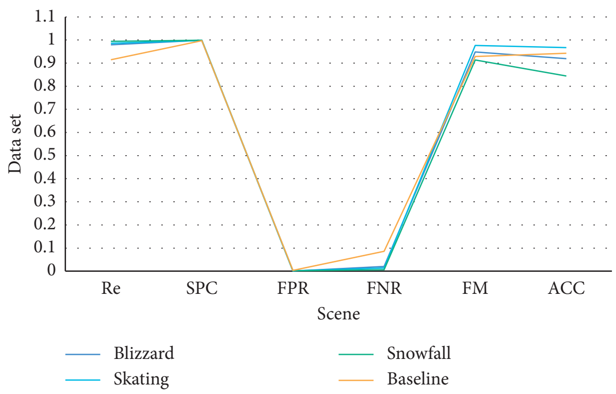

FIGURE 9: Performance of fine-tuned subnet-4 in various scenarios in data visualization.

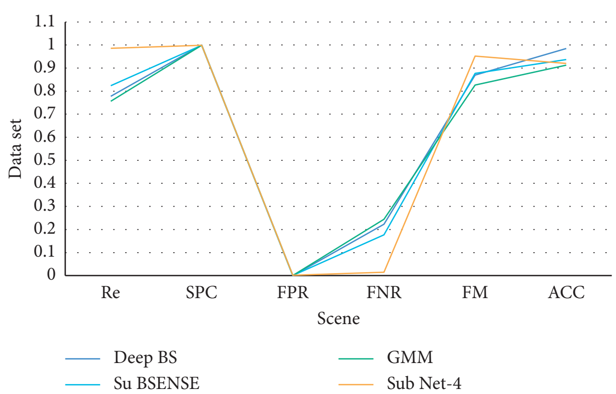

FIGURE 10: Average performance of different algorithms in some scenes of badWeather.

design pattern model's performance on the benchmark dataset has improved (the F score has increased from 0.9109 to 0.9284), implying that increasing the amount of data helps to improve the robustness of the data visualization and visual communication design pattern model. It is easy to see how much better the encoding and decoding algorithms are than the original GMM algorithm and how much better the antinoise ability is while effectively solving the "hole" problem.

5. Conclusions

Data visualization has taken off in this era of rapid advancement in computer technology and information technology, thanks to the power of science and technology. Traditional data charts have been transformed into visual communication design mode, which is of great benefit in guiding the general public to understand highly specialized data information and relieving data visualization resistance. The interactive operation mode is more user-friendly. The key to encoding and decoding is a thorough understanding of the design pattern of data visualization and visual communication, as well as the designer's improvement of drawing, the audience's adjustment, and the designer's interaction with the audience. The decoder's overall design is organized and divided into modules, with handshake signals defined. On this foundation, the decoding algorithm flow of data visualization and visual communication design pattern and the decoding system's hardware implementation scheme are thoroughly examined, and the majority of the modules are designed and simulated. The symmetry of the sine coefficient in data visualization and visual communication design pattern operation is used to improve the original algorithm, which can significantly reduce the times of addition and multiplication, based on careful analysis of the decoding algorithm of data visualization and visual communication design pattern.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Key Frame Extraction Method of Music and Dance Video Based on Multicore Learning Feature Fusion

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The purpose of video key frame extraction is to use as few video frames as possible to represent as much video content as possible, reduce redundant video frames, and reduce the amount of computation, so as to facilitate quick browsing, content summarization, indexing, and retrieval of videos. In this paper, a method of dance motion recognition and video key frame extraction based on multifeature fusion is designed to learn the complicated and changeable dancer motion recognition. Firstly, multiple features are fused, and then the similarity is measured. Then, the video sequences are clustered by the clustering algorithm according to the scene. Finally, the key frames are extracted according to the minimum amount of motion. Through the quantitative analysis and research of the simulation results of different models, it can be seen that the model proposed in this paper can show high performance and stability. The breakthrough of video clip retrieval technology is bound to effectively promote the inheritance and development of dance, which is of great theoretical significance and practical value.

1. Introduction

With the continuous progress of multimedia technology and computer network, video and images show more positive significance in daily life, and the amount of video image data is increasing geometrically [1]. Therefore, for video data, how to index it and finally retrieve it quickly and accurately has become an urgent demand [2]. At first, the way of human communication was sound and language, and then words and graphics appeared [3]. In modern civilized society, the emergence of digital products such as digital cameras and digital video cameras has further made images and videos a popular way of information exchange [4]. Video has developed into the main carrier of information dissemination, enriching people's lives and bringing opportunities for the vigorous development of artificial intelligence and big data industry [5]. Among them, computer vision plays a vital role. Motion recognition is a very challenging subject in the current research field of computer vision. Its purpose is to analyze video data using image processing [6–8] and classification recognition technology [9,10] to recognize human motion [11]. Effective fragment retrieval of dance video can help dance teachers arrange dance and assist Dance Teaching [12]. The breakthrough of dance video retrieval technology will effectively promote the inheritance and development of dance.

Every day, a large amount of video data is generated, and digital video is becoming more widely used in all aspects. With the large increase in video data, video database management systems have received a lot of attention and have a lot of potential [13]. Due to the large amount of video data, the current standard practice is to first detect and segment the video and then select several representative still image frames, referred to as key frames, from the lens to represent the visual content of the entire lens [14]. On the basis of video segmentation into shots, key frame extraction analyzes the color, texture, and other characteristics of image frames in the lens and finds the image frame that best represents the lens content based on the relationship between frames [15]. There are several common key frame extraction methods available today, but most of them are only effective for specific videos and cannot be applied to other videos, and the extracted key frames do not always represent the video's main content [16]. Using the key frame as the index, extract the key frame set from the video sequence, summarize the original video content from high-level semantic information to low-level visual features, and retrieve the original video content. As a result, the number and quality of extracted key frames have a direct impact on the final search results' efficiency and accuracy [17]. Based on this, this paper proposes a multifeature fusion-based video key frame extraction method and applies it to dance action recognition.

Image retrieval is an early well-known video retrieval technology. It distinguishes the video by manually labeling some text descriptions or numbers. When retrieving the video, it uses the labeled label to search [18]. The content-based video retrieval method retrieves massive video data in the database according to the relationship between video content and context, in order to provide a visual feature algorithm that can automatically understand and recognize video in an unsupervised state [19]. Content-based video retrieval extracts the lowest level features to the high-level semantic features, analyzes and processes the video, automatically establishes an index of video data, and retrieves and browses according to the index [20]. The research results of motion recognition technology based on dance video not only are conducive to the analysis of dance video by dance professionals, but also can be used for teaching, protection, and excavation of artistic and cultural heritage. In addition, the research of motion recognition method based on dance video will also play a positive role in the research of human motion recognition in a large number of real and complex environments, enriching the application fields of motion recognition technology [21]. If the motion recognition technology is applied to the analysis of these music and dance videos, so as to obtain the organically related music and dance motion fragments, it can not only reduce the work intensity of dance professionals and facilitate the retrieval of music and dance video data, but also make the automatic dance arrangement system more efficient.

Firstly, this paper shows the feature extraction process and model in the key frame extraction method of music and dance video and then applies the feature fusion and recognition method to the key frame extraction of music and dance video. The simulation results show that the method proposed in this paper has high performance and accuracy.

2. Related Work

Literature [22] extracts the features of edge force field by Boosting classifier and designs a human posture estimation algorithm based on component detection. Literature [23] proposed an appearance model combining histogram and color features to estimate the pose of dance movements. However, due to the complexity of human posture changes, it is difficult for traditional methods to achieve effective posture estimation. Therefore, the method based on deep learning [9,24,25] is gradually used for human posture estimation. Literature [26] designed an hourglass-shaped neural network structure to extract multiscale features and identify dance movements. Literature [27] proposed a method to obtain human skeleton map by partial affinity domain. In addition, many dance movement recognition algorithms based on deep learning have been proposed one after another. Literature [28] takes out a fixed number of image frames at the first frame, the first frame, the second frame, or the equally spaced positions as key frames. Literature [29] selects multiple key frames according to the significant changes between frames. Firstly, the first frame of the shot is taken as the key frame, and then the difference between the previous key frame and the remaining frames is calculated. If the difference is greater than a certain threshold, another key frame is selected. Literature [30] proposed a method of extracting key frames based on shot activity. Firstly, the histograms of internal frames and reference frames were calculated, and then the activity marks were calculated. According to the curve of activity, the frame with local minimum is regarded as the key frame.

These methods often do not consider the change and complexity of the visual content in the lens. Most of the more complicated methods measure the similarity between any two frames in the shot by means of some underlying features such as color, texture, and motion information and divide all frames in the shot into different classes by combining threshold or clustering and then select representative frames from each class as key frames. Therefore, this paper proposes a method of dance motion recognition and video key frame extraction based on multifeature fusion, which is used to learn complex and changeable dance motion recognition. Through the steps of preprocessing, classifying, and indexing video data, a practical, convenient, and economical video retrieval system is developed, and the mechanism of video information retrieval and browsing scheme is improved.

3. Key Frame Extraction Method of Music and Dance Video

The relationship between video data units in terms of operation is unclear. The relationship between video segments is complex and difficult to define precisely, which introduces a slew of new issues into the setup and operation of a video database. It is difficult to process unstructured video data directly because it is difficult to measure the similarity between two unstructured data [31]. The successful application of motion recognition technology in other fields provides us with a sufficient theoretical foundation to apply it to dance video motion recognition. Currently, there are a large number of music and dance video materials, and professionals must spend a significant amount of time listening to and looking at these dance video materials, which is clearly inefficient. A specific action category is thought to have generated the image sequence in the video. As a result, the single-layer motion recognition method is primarily concerned with how to represent and match videos [32]. One or more frames of images that reflect the main information content in a group of shots and can express the shot content succinctly are known as key frames. Because each shot is taken in the same scene, each frame of images in the same shot contains a lot of the same information. Feature extraction is usually the first step in motion recognition research.

The feature extraction process mainly consists of three parts: the first part is to extract directional gradient histogram features by using the method of accumulating edge features; the second part mainly extracts the directional histogram features of optical flow from the dance data set; the third part extracts the corresponding audio stream files from the dance action videos and then extracts the audio signature features from the audio stream files. The specific feature extraction process is shown in Figure 1.

To achieve the data compression effect, only the key frames of the shot can be stored due to storage capacity. Second, key frames are used to represent shots, similar to keywords in text retrieval, so video shots can be processed by image retrieval technology. Key frame extraction has been made difficult by the variability of dance movements and the presence of too many redundant movements. This paper will calculate the optical flow of the image sequence of the dance action video after framing in order to extract a set of key frames with less redundancy and can summarize the video content. For smaller objects, this method can match movements with large displacement and estimate optical flow. At the moment, there is not much of a difference in the visual characteristics and content of the image frame.

When a video stream is segmented into a series of semantically independent shots, although the amount of data that needs to be analyzed and processed is segmented, the amount of image data in the shots is still huge. To reduce the amount of data in video index, it is more important to facilitate users to retrieve video information and improve retrieval efficiency. It is necessary to extract one or more key frames from a shot according to the complexity of the shot content [33]. Since the shot is composed of frame images that are continuous in time and highly relevant in content, the most irrelevant frames can be selected as the key frames of the shot to contain the most information. The specific algorithm is to let $f_i\,(i = 1, 2, \ldots, N)$ be the feature vector of the i-th frame of a shot with N frames of images and define the correlation coefficient between feature vectors f_i and f_j as

$$\rho_{ij} = \frac{C_{ij}}{\sigma_i \sigma_j}. \tag{1}$$

Here, $C_{ij} = (f_i - m)(f_j - m)$, $\sigma_i^2 = C_{ii}$, and m is the mean vector. Select the k frame $r_1, r_2, \ldots, r_k \in \{1, 2, \ldots, N\}$ with the smallest correlation as the key frame ($k << N$):

$$R\left(f_{r_1}, f_{r_2}, \Lambda, f_{r_k}\right) = \left\{\sum_{i=1}^{r_{k-1}} \sum_{j=1}^{r_k} \left(\rho_{r_i, r_k}\right)^2\right\}^{\frac{1}{2}}. \tag{2}$$

The main problem of the above method is that the amount of calculation is too large, because it is necessary to calculate the correlation for any two frames. The method is simplified, and 1 to 3 frames of images are automatically extracted as key frames according to the different characteristics of the lens.

Let f denote a frame of image and $S = \{f_m, m = 1, 2, \ldots, N\}$ denote a shot with N frames. Take image frames f_1, $f_{N/2}$, and f_N as candidate key frames. Define the distance between two images f_i and f_j as

$$D\left(f_i, f_j\right) = \sum_{x,y} \left| f_i(x, y) - f_j(x, y) \right|. \tag{3}$$

When extracting key frames, first calculate the distance between two candidate key frames, namely, $D(f_1, f_{N/2}), D(f_1, f_N), D(f_{N/2}, f_N)$. Compare them with a predetermined threshold T. If they are both smaller than T, it means that they are relatively close. At this time, take $f_{N/2}$ as the key frame. If they are all larger than t, it means that there is a big gap between them. At this time, all three frames are regarded as key frames. In other cases, take the two images with the largest distance as key frames.

Key frames are digital images that contain the most intuitive information summary for users of video retrieval systems. The summary should as much as possible express the main content of the shot, so that the user understands the content to be expressed in the video from the start. The envelope and music energy features of music will be extracted in this paper, and the music feature and entropy sequence will be fused to produce a music-related entropy sequence. Figure 2 depicts the main flow of video key frame extraction.

Use the optical flow calculation method to obtain the movement characteristics of dance videos:

$$\begin{aligned}
E(w) &= E_{\text{color}}(w) + \gamma E_{\text{grad}}(w) + \alpha E_{\text{smooth}}(w) \\
&\quad + \beta E_{\text{match}}(w, w_l) + E_{\text{desc}}(w_1), \\
E_{\text{color}}(w) &= \int_{\Omega} \psi\left(\left|\nabla I_2(x + w(x)) - \nabla I_1(x)\right|^2\right) \mathrm{d}x, \\
E_{\text{grad}}(w) &= \int_{\Omega} \psi\left(\left|\nabla I_2(x + w(x)) - \nabla I_1(x)\right|^2\right) \mathrm{d}x, \\
E_{\text{smooth}}(w) &= \int_{\Omega} \psi\left(|\nabla \mu(x)|^2 + \left|\nabla \nu(x)^2\right|\right) \mathrm{d}x, \\
E_{\text{match}}(w) &= \int \delta(x) \rho(x) \psi\left(\left|w(x) - w_1(x)\right|^2\right) \mathrm{d}x, \\
E_{\text{desc}}(w_1) &= \int \delta(x) \left|f_2(x + w_1(x)) - f_1(x)\right|^2 \mathrm{d}x.
\end{aligned} \tag{4}$$

Here, α, $ß$, and γ are adjustable weight parameters, and $E_{\text{color}}(w)$ is the assumption of brightness invariance, which is applicable to both color images and grayscale images. The influence of light is inevitable. Therefore, in order to reduce the influence of light, it is necessary to add gradient constraint $E_{\text{grad}}(w)$ on this basis and then smooth it through $E_{\text{smooth}}(w)$. The last two items are to construct descriptor matching and find its minimum value through variable models and optimizations.

Calculate the entropy value of the current optical flow diagram in chronological order:

$$S = -\sum_{k}^{m} p_k \log_2 p_k. \tag{5}$$

Here, p_k represents the proportion of pixels with a gray value of k in the image, m represents the gray level, and S is

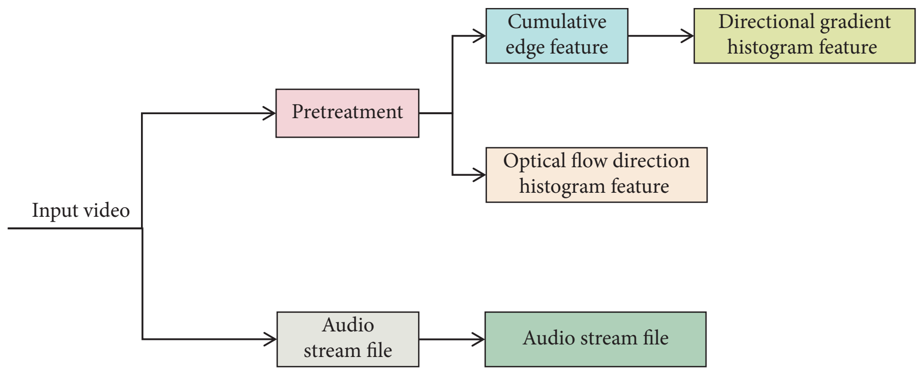

Figure 1: Feature extraction process.

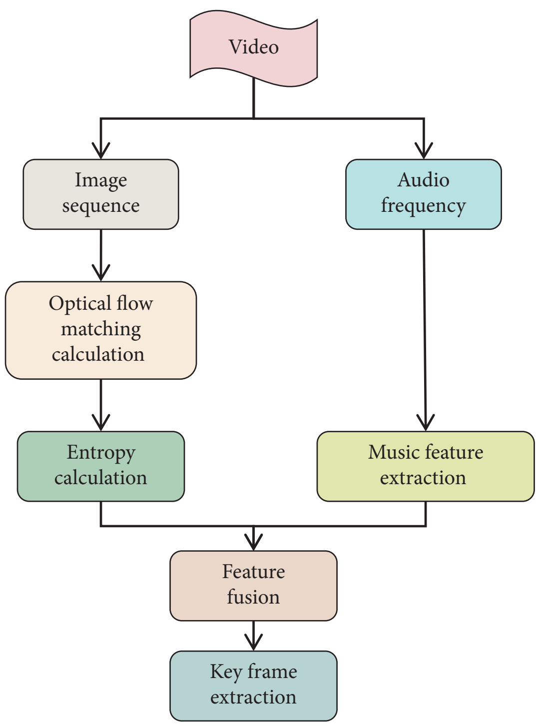

Figure 2: Dance key frame extraction process.

the entropy value. The greater the amount of information contained in the image, the greater the entropy value.

In the process of correspondence between audio and dance movements, the length of dance video, the frame number of images, and the frame rate of video are known. Then, the standard deviation is used to carry out interval operation to obtain the corresponding audio value per second, and the audio value and entropy value sequence are subjected to feature fusion.

4. Feature Fusion and Recognition

Although multiple key frames can more effectively describe the information expressed by shots than a single one, the likelihood of repeated or redundant video frames increases dramatically as the number of key frames increases. As a result, the focus and difficulty of key frame extraction technology is how to select the appropriate key frames that can not only represent the shot information, but also improve retrieval efficiency and reduce the amount of video index data. Optical flow directional histogram features are used to describe the motion information of dance movements, while directional histogram features are used to describe the local appearance and shape features of dance movements. Furthermore, the influence of music on dance should be considered when studying dance action recognition. All dancers perform with music playing in the background, and the type of music is related to the type of dance. Audio features, on the other hand, contain a lot of information, making them an important auxiliary feature that can help reduce the impact of self-occlusion on dance movements. Figure 3 depicts the multicore learning feature fusion process.

Suppose there are p dance moves $x_1, x_2, \ldots, x_p$ and category $y_1, y_2, \ldots, y_p$ in the dance data set. At the same time, the G kernel functions corresponding to the Histogram of Oriented Gradient (HOG) feature are defined as $k_g(x_i, x_j)$, the F kernel functions corresponding to the Histograms of Oriented Optical Flow (HOF) feature are defined as $k_f(x_i, x_j)$, $f = 1, 2, \ldots, F$, and the M kernel functions corresponding to the audio signature feature are defined as $k_m(x_i, x_j)$, $m = 1, 2, \ldots, M$. The linear combination of the kernel function combining the above three characteristics can be expressed by the following formula:

$$S = -\sum_{k}^{m} p_k \log_2 p_k. \tag{6}$$

Formula (6) satisfies $\beta_g \geq 0 \forall g, \beta_f \geq 0 \forall f, \beta_m \geq 0 \forall m, \sum_{g=1}^{G} \beta_g + \sum_{f=1}^{F} \beta_f + \sum_{m=1}^{M} \beta_m = 1$. β_g, β_f, and β_m are the weights of the corresponding kernel functions.

In order to express the content of the shot as completely as possible, conservative principles will be adopted when extracting key frames. When analyzing a video, if all the image frames at every moment are used, too many redundant image frames will be used. Therefore, people think of extracting key frames from thousands of image frames.

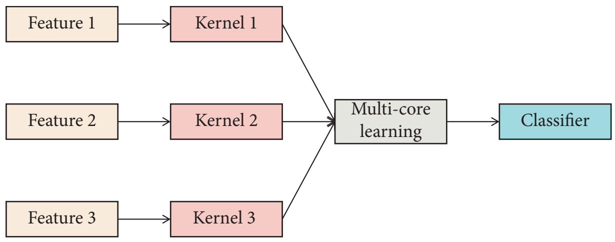

Figure 3: Multicore learning feature fusion process.

The use of key frames greatly reduces the amount of data in video index and also provides an organizational framework for searching and browsing videos.

5. Result Analysis and Discussion

In the past, motion recognition methods that relied on a single feature could only describe one aspect of human motion in video, but they could not effectively describe human motion. As a result, motion recognition research has turned to the multifeature fusion method. Combining different features can more comprehensively describe human motion in video, resulting in a better recognition effect. The dance video retrieval database is made up of key frames and video clips that have been summarized. Kernel functions play different roles in classification depending on the problem. The goal of multicore learning is to improve the classification effect by giving different kernel functions reasonable weights and combining multiple kernel functions to describe features more thoroughly. The data set is used to extract directional gradient histogram features, optical flow directional histogram features, and audio features for the dance motion recognition method described in this paper. Figure 4 shows the entire appearance feature of the audio signal as a result of envelope feature extraction from dance video accompaniment music.

The dance video is composed of a series of dance movements, and the coherent dance movements reflect more or less amount of movement. The motion information in the dance video is expressed by optical flow, and then the information in each optical flowchart is counted by entropy. Entropy sequence and music features are fused to obtain a music-related entropy sequence. Then, the key frames are selected by the threshold, and when the threshold is set, it will be compared with the key frame set selected by several users to select the best threshold suitable for the video. The matching of feature points starts from the first frame of the query segment, and the frames in the query segment are sequentially compared with the frames in the key frame set. Then select a key frame that is most similar to the frame of the query fragment. Video clips can be described by one or several key frames. No matter what level of similarity matching, if there are some dissimilar parts between the query segment and some subsegments, shots, or frames in the video segment, such segments are discontinuous. When this situation produces more dissimilarities, it indicates that the similarity between the two fragments is lower. Adaptive key frame extraction algorithm based on unsupervised

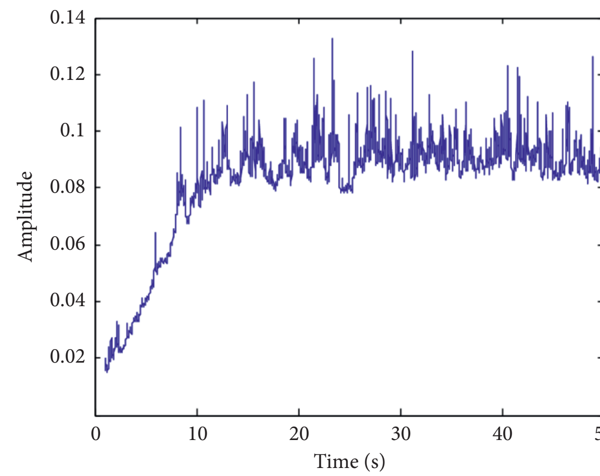

Figure 4: Envelope extracted from accompaniment music of dance video.

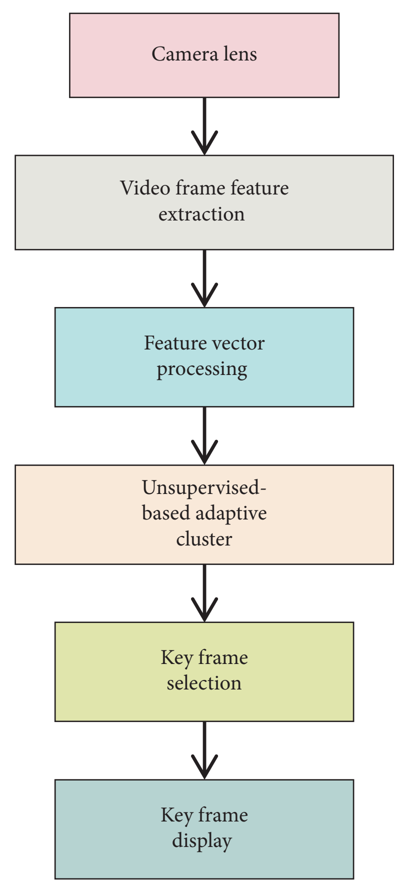

Figure 5: Algorithm implementation process.

clustering is used to extract key frames for different types of shots, as shown in Figure 5.

Different combinations of repetitive dance movements are frequently used to create dance videos. Similar dance movements will appear in various types of dance videos during this process, and eventually, everyone will follow this choreography pattern. We can discover that dance movements in dance videos are closely related to music through segment retrieval of dance videos. All of the video frames in the shot are treated as independent subclusters at the start of merging, and pairwise similarity is calculated. The two most similar subcategories, that is, the least similar, are chosen and merged into a new subcategory. Merge according to this cycle, then wait until an automatic merging stop rule is satisfied before getting the final clustering result. We should extract the features of the image frames in the video first, then process the features of the image frames with the algorithm, and finally extract the key frames, regardless of which algorithm we use to extract the key frames. Figure 6 shows a simulation comparison of image key frame extraction reliability optimization.

The motion features of video describing human motion information are often essential features in the research based on motion recognition, and the optical flow method is usually used to extract the features in some related motion recognition research at present. Texture is a value calculated from the texture image, which quantifies the features of gray scale changes inside the texture. Generally, texture features are related to the position, direction, size, and shape of the texture but have nothing to do with the average gray level. The purpose of feature extraction is to transform the spatial structure difference of random texture or geometric texture into the difference of feature gray value and use some mathematical models to describe the texture information of the image, including the smoothness, sparseness, and regularity of the image area. The linear regression curve is calculated according to the stepwise multiple linear regression equation, as shown in Figure 7.

FS denotes a method of searching that uses F7 layer features, HS denotes a method of searching that uses coarse searching, and HFS denotes a method of searching that goes from coarse to fine. Figure 8 depicts the effect of various algorithmic features on the retrieved video key frames. Clearly, HFS is the first to demonstrate good retrieval accuracy, implying that the video GIS data retrieval algorithm can obtain richer detail features of video GIS key frames. When retrieving more than 13 images, however, the retrieval effect of HS outperforms that of FS. This demonstrates that the binary code generated by this algorithm has a high level of discrimination and contains a lot of semantic information.

For a video containing multiple shots, the key frame fidelity is the average of the fidelity of each shot and the group of key frames. The purpose of extracting key frames is to use as few video frames as possible to represent as much video content as possible, so the higher the compression rate, the more effective this key frame extraction method. Make the estimate continuous at the threshold. The shrinking trend of the adaptive nonlinear curve is shown in Figure 9.

The purpose of key frame extraction is to replace the whole video with few image frames, so as to facilitate the viewer to quickly browse the content of the whole video and reduce the amount of video data, thus making the video processing more convenient and faster. Therefore, the effectiveness of the key frame extraction method should be considered first, and then its computational complexity and

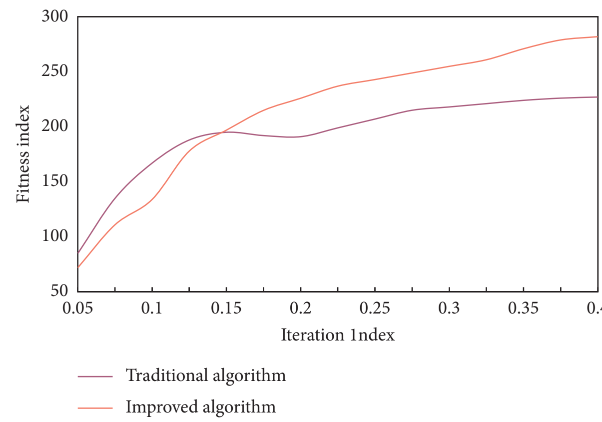

Figure 6: Image key frame extraction optimization simulation comparison.

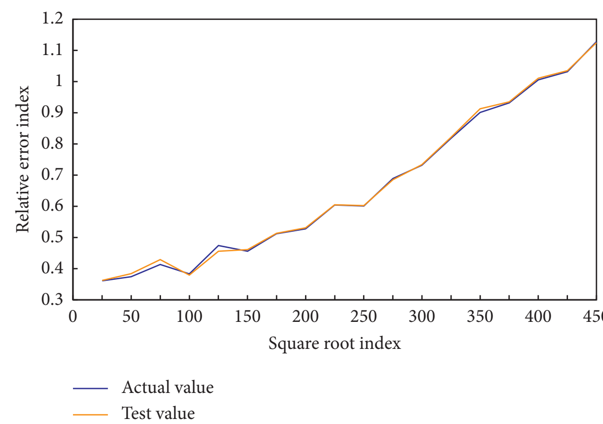

Figure 7: The relationship between the actual value and the calculated value of stepwise linear regression.

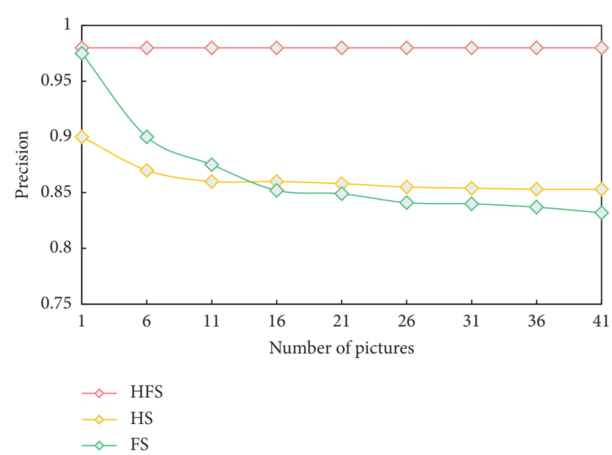

Figure 8: Retrieval effect of different network characteristics.

efficiency should be considered on the premise of effectiveness. The experimental results of the comparison between this method and the benchmark method in four dance combinations are shown in Figure 10. In the recognition of four dance combinations, the recognition rate of this method is higher than that of the benchmark method. The

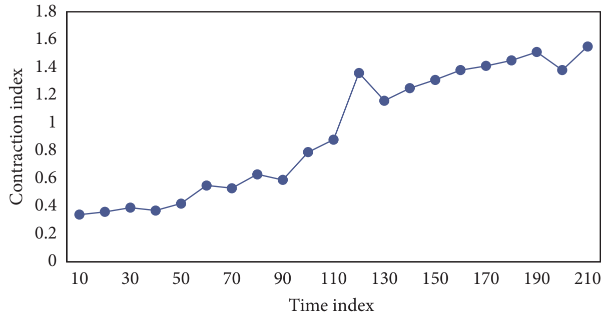

Figure 9: Adaptive nonlinear curve shrinking trend.

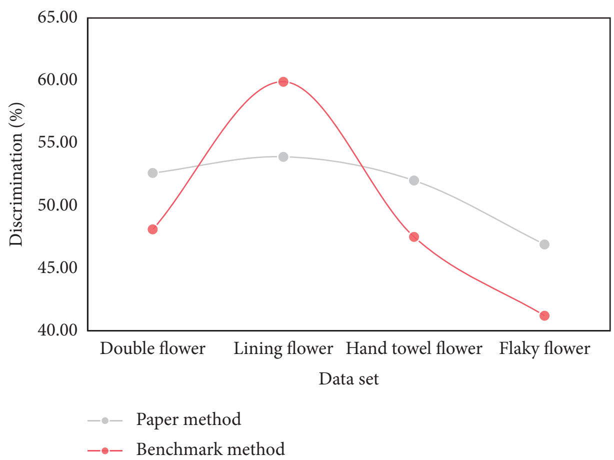

Figure 10: Comparison of the recognition rate.

recognition rate of this method is 53.9%, which is lower than 59.9% of the benchmark method. In other combinations, the performance of this method is better than that of the benchmark method, especially when the similarity of dance movements in the combination of towel and flower is too high.

When the dance movements are too complicated and there are similar movements and self-occlusion, the benchmark method based on trajectory feature fusion can not accurately represent the dance movements. The fusion algorithm in this paper can avoid the above influence to a certain extent, thus improving the recognition rate of dance, and it also verifies the effectiveness of the algorithm. The experimental results show that not only is the algorithm in this paper relatively simple in calculation, but also the extracted key frames can effectively summarize the main content of the video, realize video compression and storage, and lay a good foundation for video retrieval and video summarization. From the perspective of the future development trend of video data mining, the requirement for video data processing technology is getting higher and higher because of the contradiction between the large amount of calculation of video processing and the short retrieval time expected by users. Moreover, with the continuous development of information technology, it is more and more difficult to process video data with various features.

6. Conclusions

The dance contains far too many repetitive dance moves, which will slow down retrieval speed when searching. As a result, this paper proposes a method for extracting key frames from music and dance videos. First, the framed video's optical flow is calculated, and the video's motion features are extracted. Music and dance are inextricably linked. The corresponding audio in the video is then extracted, along with its features. This paper presents an unsupervised automatic video key frame extraction method. This method uses simple cyclic merging to cluster video frames and creates an automatic merging stop rule to stop merging when the clustering results are optimized. There is no need to set parameters or prior knowledge in advance for this video frame clustering process. The results of the experiments on multiple test videos show that the extracted key frames can effectively represent the video's main visual content.

Although some progress has been made in dance motion recognition research in this paper, the recognition rate of dance video motion recognition research is currently low, owing to the complexity of the dance motion and the inadequacy of existing methods for dance motion recognition. Because of the complexity of dance movements, the dance data set we created at this point only considers solo dance situations, ignoring changing stage scenes and other factors. More research will be done in the future on how to apply music theory-related content to create a more accurate mapping between music and dance movements, in order to improve dance movement recognition accuracy. [33].

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

High-Dynamic Dance Motion Recognition Method Based on Video Visual Analysis

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In the field of computer vision, high-dynamic dance motion recognition is a difficult problem to solve. Its goal is to recognize human motion by analyzing video data using image processing and classification recognition technology. Video multifeature fusion has sparked a surge in research in a variety of fields. Several pixel points that can be distinguished and displayed in several adjacent images that can reflect their characteristics are referred to as multifeature fusion. It is responsible for a significant portion of the similarity results between the two video segments. Motion recognition relies heavily on video multifeature fusion, which has a direct impact on the robustness and accuracy of recognition results. The directional gradient histogram features, optical flow direction histogram features, and audio features extracted from dance video are used to characterize dance movements after all of the characteristics of dance movements have been considered. This paper focuses on the high-dynamic dance action recognition method based on video multifeature fusion, which aims to combine high-dynamic dance action recognition and video multifeature fusion.

1. Introduction

Video information has become widely used in many fields as a result of the development of computer vision and video image processing technology [1]. Computer vision is widely used in medical, transportation, and other fields as an auxiliary means of human vision and an important part of automation systems [2]. Users hope to retrieve and query specific action clips in high-dynamic dance video as easily and quickly as they retrieve and query text information and then obtain specific action clips of interest for playback and browsing [3]. Human posture estimation technology's application field of dance movement recognition is important. Dance movement recognition technology can assist dancers in identifying and correcting incorrect postures, as well as contributing to intelligent dance auxiliary training. Action recognition can help with game design in addition to dance learning and teaching [4]. Firstly, the actions in the dance image video are recognized, and then the action model is further established according to the recognition results to generate the character actions in the game, so as to greatly enhance the user experience effect. The research on human motion recognition in China started relatively late, but it developed rapidly. At present, many units are engaged in intelligent video analysis and research and have made some breakthroughs in related fields. Well known is the research on the key technology of intelligent surveillance video analysis carried out by the Institute of Automation, Chinese Academy of Sciences, which automatically analyzes the video captured from the camera, locates, tracks, and identifies the moving targets in it, realizes the management of daily surveillance, and makes timely response to abnormal situations. In the field of human motion recognition, some significant research achievements have been made after years of development. The research has also broadened from simple action analysis and recognition in a simple background to multiperson complex actions in a complex background. In the current research field of computer vision, motion recognition is a very difficult subject [5, 6]. Its goal is to recognize human motion [7] by analyzing video data [8] using image processing and classification recognition technology [9, 10].

In the research of motion recognition, video multifeature fusion is usually the first step [11]. After fully considering the characteristics of dance movements, the directional gradient histogram features, optical flow direction histogram features, and audio features extracted from dance video are used to characterize dance movements. Key frames are defined as some representative image frames with less redundancy in video. The directional gradient histogram feature is used to describe the local appearance and shape features of dance movements, and the optical flow direction histogram feature is used to describe the motion information of dance movements. In addition, the research on dance action recognition should also consider the impact of music on dance. Dance performers perform dance with the accompaniment of music, and the style of music is related to the type of dance. The key frame extraction has been made difficult by the variability of dance movements and the presence of too many redundant movements. This paper will calculate the optical flow of the image sequence of dance action video after framing in order to extract a set of key frames with less redundancy and can summarize the video content. This method can match large-distance actions and estimate optical flow for small objects. The accuracy of action recognition results and the robustness of action recognition methods are both influenced by the extracted features. Video multifeature fusion has sparked a surge in research in a variety of fields. Several pixel points that can be distinguished and displayed in several adjacent images that can reflect their characteristics are referred to as multifeature fusion [12, 13]. The directional gradient histogram features, optical flow direction histogram features, and audio features extracted from dance video are used to characterize dance movements after all of the characteristics of dance movements have been considered.

This fusion method produces new feature vectors with excessively high dimensions and redundant information. Although this method can improve classification effect to a degree, increasing the feature vector dimension increases computational cost, and the new features formed by fusion contain many features, resulting in the same weight of each feature [14, 15]. Such features with a poor classification effect are given the same weight as those with a good classification effect, affecting classification accuracy to some extent [16]. Video multifeature fusion plays a very important role in motion recognition, which directly affects the robustness and accuracy of recognition results [17, 18]. Video multifeature fusion is based on the trajectory formed by the connection of multiple feature points, and then extracting the trajectory based features is a good choice. It not only combines the global spatiotemporal volume features with local feature points, but also includes the temporal and partial spatial relationship between feature points, so that the extracted features can cover more abundant information of moving objects. The video multifeature fusion method can assign weights to each feature according to their contribution to classification through the decision-making mechanism, so it can let a variety of features give full play to their respective advantages, so as to improve the classification accuracy. Video multifeature fusion is a widely used fusion method in multifeature fusion.

2. Related Work

According to [19], some authoritative journals and important academic conferences in relevant fields around the world, such as IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI) and International Journal of Computer Vision (IJCV), include motion analysis and recognition in video as one of the main research contents. A major visual monitoring project was established by the US Defense Advanced Research Projects Agency, which included many well-known universities. Its main research focus is on the intelligent analysis and comprehension of surveillance videos in a variety of settings, including battlefields and everyday settings. This study can achieve human motion region segmentation, multiperson tracking, and basic human motion analysis and recognition. Literature [20] shows that, by tracking the trajectory formed by several points on the human body, the recognition of simple actions such as walking and running is realized, which opens the door of action recognition research. Literature [21] points out that, in the process of learning and understanding content-based video retrieval, action video retrieval has become the mainstream and action video generally involves running, jumping, swimming, weightlifting, etc. Literature [22] shows that there is too little research on dance video because dance is a continuous and changeable limb movement, and different types of dance will have limb movements with different intensity changes. Literature [23] mentions that, through the big data analysis method, the main idea of content-based video retrieval technology is, given an image, similarity matching carried out according to the content in the image to find videos with the same or similar content. Literature [24] pointed out that image retrieval is a well-known video retrieval technology earlier. It distinguishes videos by manually marking some text descriptions or numbers, and when searching videos, it uses marked labels to search. Literature [25] reveals that, according to research, a large number of domestic and international scientific research institutions and related scholars are dedicated to the study of motion recognition based on video and have made significant contributions to the field's development. Domestic motion recognition research began relatively late, according to [26], using the big data analysis method. Many domestic universities and scientific research institutions have conducted motion recognition research as the application of motion recognition becomes more widespread. According to [27], features with a poor classification effect have the same weight as those with a good classification effect, which will affect classification accuracy to some extent.

3. Theory and Technology Related to High-Dynamic Dance Movement Recognition

3.1. Dance Movement Recognition Theory. Dance motion recognition has advanced to the level of motion recognition, as opposed to low-level motion recognition such as gesture recognition and simple body motion recognition. The term "flexible force sensor" refers to the material in which it is made. The force between irregular contact surfaces can be measured with a flexible force sensor. The flexible force sensor is an array of pressure sensitive points that can be seen from the outside. The first step in high-dynamic dance movement recognition was to use computers to perceive people's movements, and then it progressed to recognizing simple movements like walking, running, and jumping. High-dynamic dance movement recognition has evolved into video movement recognition, which recognizes human movements in videos as a series of simple movements. There will be multiple types of actions in each video frame sequence, and each type of action will contain multiple simple actions. Every simple action is made up of a variety of human body positions. The connection of transition actions between actions allows all types of actions to be coherent and smooth. The single step gait cycle's total pressure curve looks like a saddle curve during normal walking. The curve has three distinct points: xmax1 represents total pressure when the heel touches the ground, xmin represents minimum total plantar pressure when the entire foot touches the ground, and xmax2 represents total plantar pressure when the front foot steps off the ground. Figure 1 depicts this.

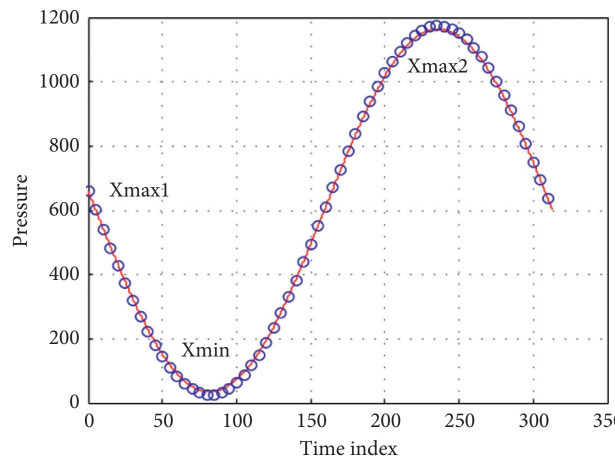

Figure 1: Characteristic points of total plantar pressure curve.

Therefore, it is difficult to obtain high recognition accuracy when a simple limb localization algorithm is used in dance movement recognition. It not only combines the global spatiotemporal volume features with local feature points, but also includes the temporal and partial spatial relationship between feature points, so that the extracted features can cover more abundant information of moving objects. In the stage of choreography, different forms of choreography should be carried out according to the characteristics of music. Similarly, in the soundtrack, it is necessary to match appropriate accompaniment music according to the rhythm and style of dance movements. The speed of dance movements is related to music. This paper will extract the accompaniment music from the video, read the accompaniment music in wav format, and then extract the envelope feature and energy feature of the music to prepare for the subsequent feature fusion, which is very helpful to the event detection of music. Dance movements usually have complex and large-scale changes, and recognizing dance movements requires a deep learning model [28, 29] to grasp the needs of each scale information when extracting features. Figure 2 is the result of envelope feature extraction for the accompaniment music of the dance video Theodora _ Africa _ wide. It shows the whole appearance characteristics of the audio signal.

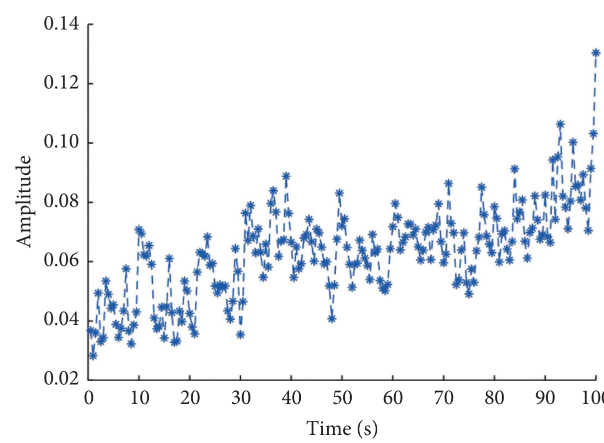

Figure 2: Dance video Theodora_ Afraid_ Envelope extracted from accompaniment music wide.

The plantar pressure data acquisition platform of the flexible force sensor designed in this paper dynamically acquires the plantar pressure information of the tester by using the characteristics of the flexible force sensor in real time. However, the high-dynamic dance moves are continuous and smooth, and it is difficult to accurately find the segmentation points, which is the main reason for the unsatisfactory segmentation of video motion sequences. Furthermore, the shortest data cannot contain the most human motion information simply by extracting key frames for motion sequence segmentation. A complete dance performance is made up of several groups of movements, each of which is made up of several simple movements such as flowers and pressing steps, and each simple movement is made up of several basic posture sequences such as raising hands and kicking legs.

3.2. Dance Movement Recognition Technology. The initial stage of high-dynamic dance motion recognition is to extract some features of images or video sequences and realize motion recognition through feature matching. Later, researchers found that the combination of low-level features and high-dynamic dance pose features can improve the accuracy of motion recognition. There are roughly two ways to obtain high-dynamic dance posture information. One is to accurately obtain the information of each joint coordinate, human skeleton, motion trajectory, and so on through motion capture equipment. Another method is to obtain the approximate joint positions and skeletons of the human body in images or videos by the method of human posture estimation. Dance movements usually have complex and large-scale changes, and recognizing dance movements requires a deep learning model to grasp the needs of each scale information when extracting features. According to the actual situation, the change trend of human posture joint position is basically the same, and there are obvious changes at the beginning and end of the action. At frame 600, i.e., after that, the curve changes disorderly, and the change cannot be accurately judged through the curve in the figure. It is necessary to obtain the concise and clear change trend of the whole pose sequence through further calculation. The position change trend of 30 joint points in human posture sequence is shown in Figure 3.

Although the change trend of human posture can be roughly seen in the figure, it is impossible to calculate and obtain the segmentation position, so it is necessary to obtain a curve that is visible and can calculate the segmentation position through further calculation. In this paper, the posture trend is expressed by calculating the average value of 30 joint positions.

$$\text{mean} = \frac{\left(\sum_{j=1}^{19} f_i\right)}{19}. \tag{1}$$

It has been discovered that using the mean value does not result in a significant change in the positions of the 30 joints in the video sequence frames but does result in a stable change trend for the regions with more chaotic changes. Figure 4 depicts the changing trend of the average position of the actor's 30 joint points over time.

Dancers often have obvious preparation time and stop time when performing dance movements. During this period, the dancers' posture basically does not change, and the distance between consecutive frames changes gently. However, most of the adjacent minima to maxima can only represent a simple movement, but not necessarily a complete dance movement. Because a complex dance movement is mostly composed of several simple movements, there are usually several extrema in a dance movement sequence.

Therefore, after finding each extreme value in the curve of continuous frame change trend, this paper uses cubic spline interpolation function to fit the curve. Firstly, the maximum value of continuous frame change data in video is obtained, and the upper envelope of data sequence is fitted by cubic spline function, and then the lower envelope of data sequence is fitted by cubic spline function. Finally, the mean value between the upper envelope and the lower envelope is calculated as the final fitting result of the current data series. The upper envelope, lower envelope, and final results of curve fitting are shown in Figures 5 and 6, respectively.

We can see the obvious segmentation points between various dance movements in a dance video after we get the fitting results. A simple action sequence can be determined by two adjacent minima, with the minima position indicating the segmentation position of the action sequence frame. Because the fitted curve may still have inaccurate segmentation positions, an action sequence must be determined using the dual control method of the difference between adjacent maxima and minima and the number of frames in the action sequence. According to statistics from

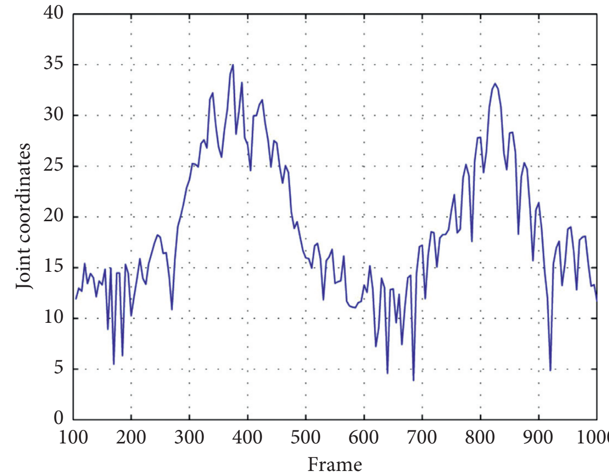

Figure 3: Trend chart of joint changes in continuous pose of actors.

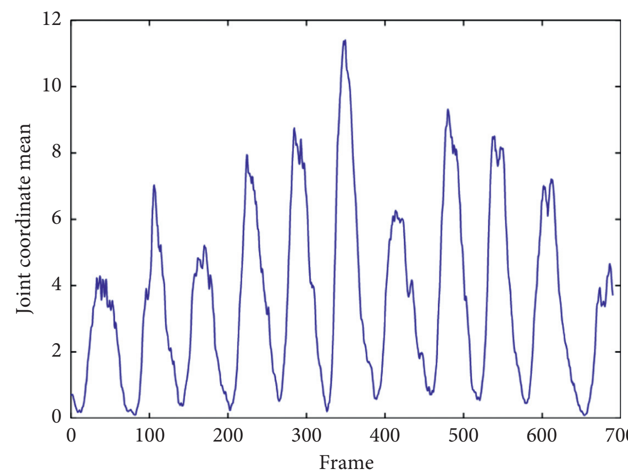

Figure 4: Average change trend of actors' continuous posture joints.

actual recorded dance situations, the dance action is a rhythmic action with a time limit of 10 seconds in the data collection process and a video frame rate of two eight beats per second, making it impossible to complete a dance action in one second at normal speed.

It is difficult to quickly and accurately retrieve specific action segments in high-dynamic dance video, and only the inherent video information contained in high-dynamic dance video data can be used to retrieve specific action segments temporarily. In order to realize the analysis and management of high-dynamic dance videos, it is necessary to study the design method of retrieval system for specific action segments in videos. People's orientation, the arrangement of limbs, and the relationship between adjacent joints all need to be inferred and identified from global context information, and local information can be accurately located. Motion recognition based on high-dynamic dance is also divided into two categories. One is to directly use the main joint information in human motion posture for similarity calculation and determine the action category by

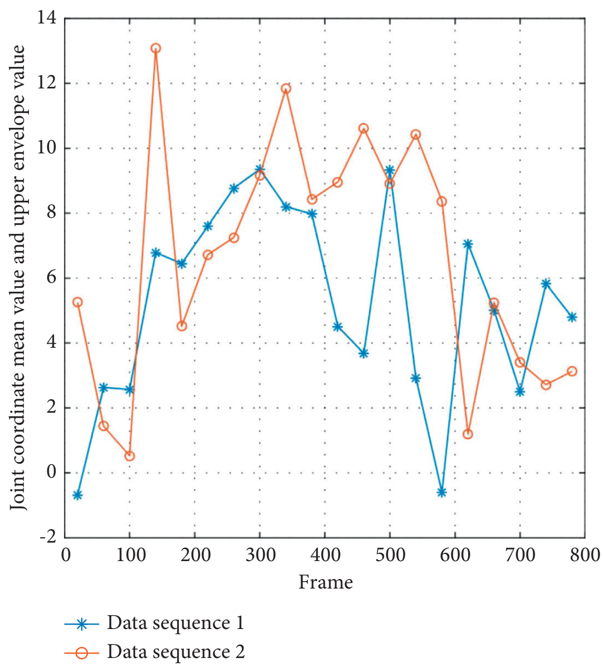

Figure 5: Curve fitting result diagram of envelope.

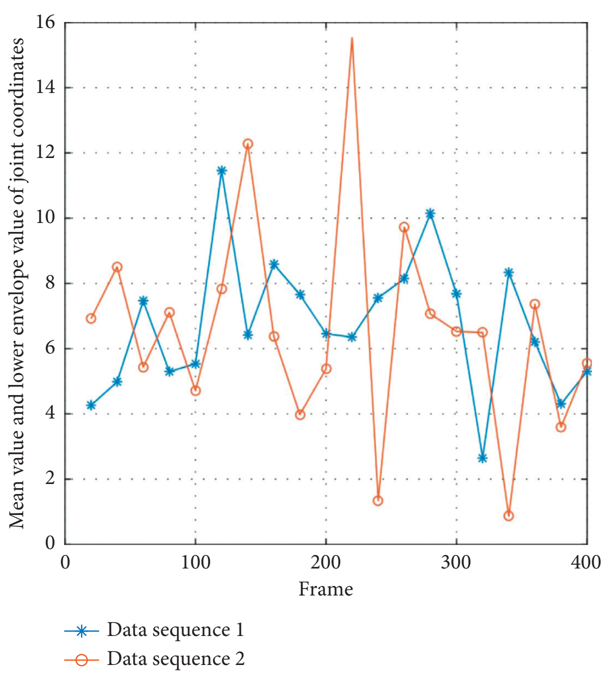

Figure 6: Lower envelope fitting results.

matching with the similarity between known actions, which is mostly used for human motion recognition in images. The other is to segment the human body in the image by using the obtained human posture, obtain the local image with each main joint position as the key, and then extract some features of the local image for recognition.

3.3. Action Recognition Method. At present, motion recognition methods are mainly divided into two categories: single-layer method and hierarchical method. Single-layer based methods usually regard actions as the characteristic category of video and use classifiers to identify actions in video. Image sequences in video are considered to be generated by specific action categories. The hierarchical method mainly identifies high-level actions by identifying simple actions or low-level atomic actions in the video. High-level complex actions can be decomposed into a sequence of subactions, which can continue to be decomposed as high-level actions until they are decomposed into atomic actions. The classification of action recognition methods is shown in Figure 7.

3.3.1. Single-Layer Method. There are two kinds of motion recognition methods based on single layer: spatiotemporal method and sequence model method. The main difference between spatiotemporal method and sequential model method is how to treat the time dimension. Different actions need to fully detect all kinds of actions, and the least crossing is better. When there are multiple types of human actions in the video, manual video editing shall be carried out and then processed according to the video containing single type of actions. Before collecting video data, most researchers choose to plan the type of action to be collected and the timing of various action videos. The sequence model method is usually better than the time and space method because it considers the sequence relationship of actions. In reality, the video cannot match the dataset's style during the research process. In most cases, the video contains a wide range of actions, and the human posture is consistent across all of them, with no discernible posture change interval. The contour feature based on the action energy map is used by the global feature, while the target cell is used by the local feature. Finally, the feature points are classified using the support vector machine's multiclass classification method.

3.3.2. Hierarchical Approach. Hierarchy-based methods usually use single-level or low-level subactions to identify high-level complex actions. A high-level complex action can be decomposed into several subaction sequences, and subactions can be decomposed as high-level actions until they are decomposed into atomic actions. At the same time, if manual video editing is used, it will take a lot of time to face professional dance movements, and nonprofessional researchers cannot guarantee the accuracy of video editing. The hierarchical method is closely related to the single-layer method to a certain extent. For example, the single-layer method can not only be used for low-level or atomic action recognition, but also be extended to the action recognition method of hierarchical model. Hierarchical methods are generally divided into three types: statistics based methods, grammar based methods, and description based methods. In addition, this paper also tested the recognition time within the range of 30 ~ 200 template images and found that the recognition time is directly proportional to the number of template images, ranging from 0.25 s to 1.75 s, as shown in Figure 8. Because the more the template images, the larger

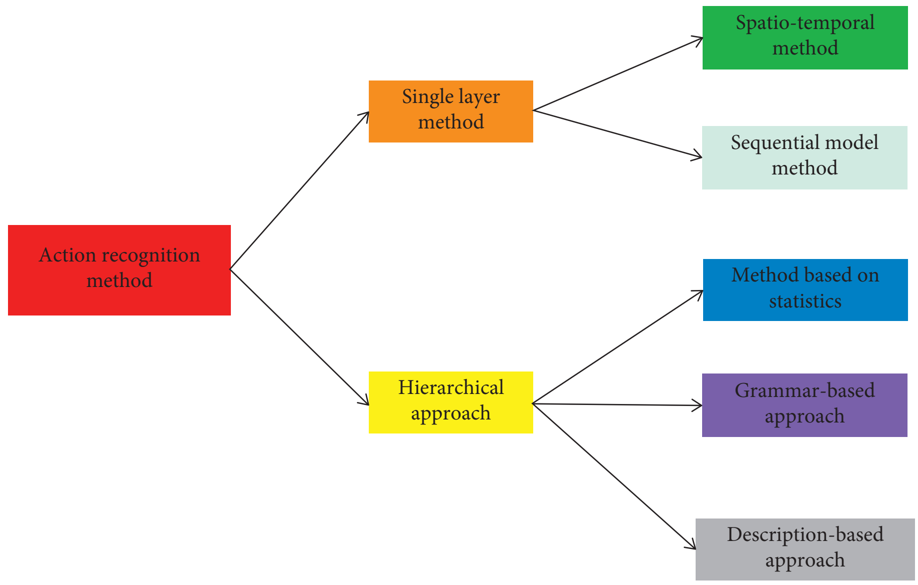

Figure 7: Classification of action recognition methods.

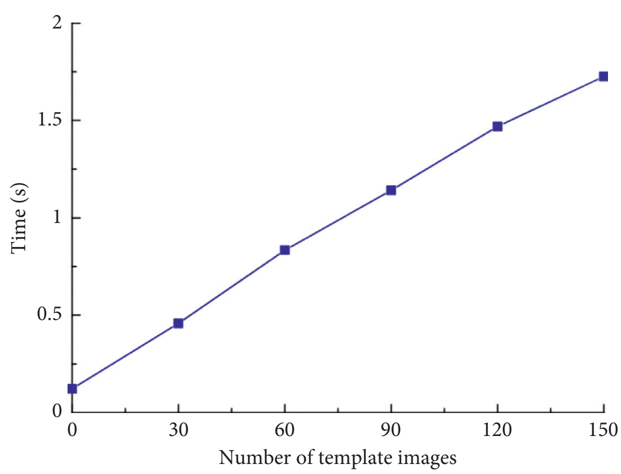

Figure 8: Identification time consumption diagram.

the scale of the template matrix, and the greater the amount of calculation during recognition operation, and the time required for calculating the distance vector between each row of the matrix and the test image is basically the same. Therefore, the recognition time increases linearly with the number of template images.

Build the model. Here, assuming that the value of a pixel at time t is XT, the probability of occurrence of XT can be obtained from

$$P\left(X_t\right) = \sum_{t=1}^{K} \omega_{i,t} \cdot \eta\left(X_t, \mu_{i,t}, \sigma_{i,t}\right), \tag{2}$$

where $\omega_{i,t}$ is the weight of the ith Gaussian distribution at time t, $\eta\left(X_t, \mu_{i,t}, \sigma_{i,t}\right)$ is the corresponding probability density function, $\mu_{i,t}$ is the corresponding mean, and similarly $\sigma_{i,t}$ is the variance. Meanwhile, the specific expression of $\eta\left(X_t, \mu_{i,t}, \sigma_{i,t}\right)$ is shown in

$$\eta\left(X_t, \mu_{i,t}, \sigma_{i,t}\right) = \frac{1}{\sqrt{2\pi\left|\sigma_{i,t}\right|}} e^{-(1/2)\left(X_t - \mu_{i,t}\right)^T \sigma_{i,t}^{-1}\left(X_t - \mu_{i,t}\right)}. \tag{3}$$

Firstly, the pixel values of the first frame of the video are assigned to the mean value of K Gaussian distributions; secondly, a larger value is assigned to their variance, and their weights are assigned the same value.

4. Video Multifeature Fusion and Recognition

4.1. Analysis of Related Problems. In the past methods of motion recognition, using a single feature can only describe one aspect of human motion in video but cannot describe human motion effectively. With the continuous evolution of dance types and forms and the increasing number of dance videos, how to browse dance videos quickly and effectively is the main problem. The movement of music and dance video is complex and changeable, and there are many repetitive movements, which brings trouble to the analysis and recognition of dance movements. The main difference between video multifeature fusion methods is the selected features and fusion strategies. Therefore, video multifeature fusion method has become a research direction of motion recognition. Fusion of different video features can describe human movements in the video more comprehensively, thus achieving better recognition effect. At present, video multifeature fusion can be divided into feature level fusion and decision level fusion.

4.1.1. Feature Layer Fusion. Feature layer fusion refers to the combination of various features to form new features; for example, there are two features $F1$ and $F2$, and a new feature vector $F3 = (f1, f2)$ is formed after feature layer fusion.

4.1.2. Integration of Decision-Making Level. The main idea of decision level fusion is to create corresponding classifiers for each feature, respectively, and then fuse the results of each feature classifier according to the selected decision mechanism to get the final classification result. The above two fusion strategies are facing certain problems. In recent years, scholars need to apply multicore learning to the research of multifeature fusion methods.

4.2. Dance Movement Recognition Method Based on Feature Fusion. The directional gradient histogram features, optical flow directional histogram features, and audio features extracted in this paper describe the characteristics of dance movements from the aspects of the appearance and shape of human dance movements in dance videos, the movement of human dance movements, and the assistance of audio features. Video clip retrieval entails locating a video clip that is similar to the query clip in the video and then determining the video clip's location in various ways. The Balletto dance video database will be used to test the effectiveness of the dance motion recognition algorithm based on video multifeature fusion. The feature fusion method has shown to be effective in the field of image classification, and it has since been applied to motion recognition research. Learning by using multiple kernel functions in training is a simple understanding. Multicore learning can effectively fuse various heterogeneous features by linear combination of kernel functions in the process of learning classifiers, so that different features can complement each other to improve recognition accuracy. Because the features used in our research contain heterogeneous features, multicore learning can effectively fuse various heterogeneous features by linear combination of kernel functions in the process of learning classifiers. The first step in high-dynamic dance motion recognition is to extract some features from images or video sequences and then match them to achieve motion recognition. Figure 9 depicts the multicore learning feature fusion process.

In practical application, according to the content and structure characteristics of the video, comprehensively measure the above points and allocate the weight. Based on this, we can find the video clip with high similarity to the query clip, as shown in Figure 10.

Therefore, it is assumed here that there are p dance movements $x1$, $X2$,..., XP and categories $Y1$, $Y2$,..., YP in the dance dataset. At the same time, the G kernel functions corresponding to the hog feature are defined as kg (Xi, XJ), $g = 1, 2, \ldots, G$, the f kernel functions corresponding to the HOF feature are defined as KF (Xi, XJ), $f = 1, 2, \ldots, F$, and the M kernel functions corresponding to the audio signature feature are km (Xi, XJ), $M = 1, 2, \ldots, M$. In this paper, the linear combination of kernel functions integrating the above three features can be expressed by the following formula:

$$\begin{gathered} k(x_i, x_j) = \sum_{g=1}^{G} \beta_g k_g(x_i, x_j) + \sum_{f=1}^{F} \beta_f k_f(x_i, x_j) + \sum_{m=1}^{M} \beta_m k_m(x_i, x_j), \\ \beta_g \geq 0 \forall g,\ \beta_f \geq 0 \forall f,\ \beta_m \geq \forall m, \quad \sum_{g=1}^{G} \beta_g + \sum_{f=1}^{F} \beta_f + \sum_{m=1}^{M} \beta_m = 1. \end{gathered} \tag{4}$$

β_g, β_f, and β_m are the weights of the corresponding kernel functions, respectively.

Arbitrarily select the two action sequences X and y after segmentation, and the lengths are L1 and L2, respectively. X and y are, respectively, expressed as

$$\begin{aligned} X &= \{x_1, x_2, \ldots, x_m, \ldots, x_{l1}\}, \\ Y &= \{y_1, y_2, \ldots, y_n, \ldots, y_{l2}\}. \end{aligned} \tag{5}$$

The mth frame of x is represented by xm, and nth frame of y is represented by yn. If $l1 = l2$, the interval between two action sequences will be calculated directly. If the two action sequences are not equal in length, the distance will be calculated after they are aligned by dynamic programming method.

In support vector machine based on multicore learning, the task of multicore learning model training stage is to learn to solve the weight β of each kernel function and the parameters α and B of support vector machine classifier. Based on the idea of simple MKL algorithm proposed by Palaiahnakote et al. introduced in the previous section, the objective function of the algorithm in this paper is defined as follows:

$$\begin{gathered} \begin{cases} \dfrac{\min}{\beta_g, \beta_f, \beta_m, a, b} & J = \dfrac{1}{2} \displaystyle\sum_{g=1}^{G} \beta_g \alpha^T K_g \alpha + \dfrac{1}{2} \sum_{f=1}^{F} \beta_f \alpha^T K_f \alpha + \dfrac{1}{2} \sum_{m=1}^{M} \beta_m \alpha^T K_m \alpha + C \sum_{i} \xi_i \\ \text{s.t.} & y_i \left[\displaystyle\sum_{G=1}^{G} \beta_g k_g(x_i) + \sum_{f=1}^{F} \beta_f K_f(x_i) + \sum_{m=1}^{M} \beta_m K_m(x_i) \right] \alpha + y_i b \geq 1 - \xi_i \forall i, \end{cases} \\ \xi_i \geq 0 \forall i, \quad \sum_{g=1}^{G} \beta_g + \sum_{f=1}^{F} \beta_f + \sum_{m=1}^{M} \beta_m = 1, \end{gathered} \tag{6}$$

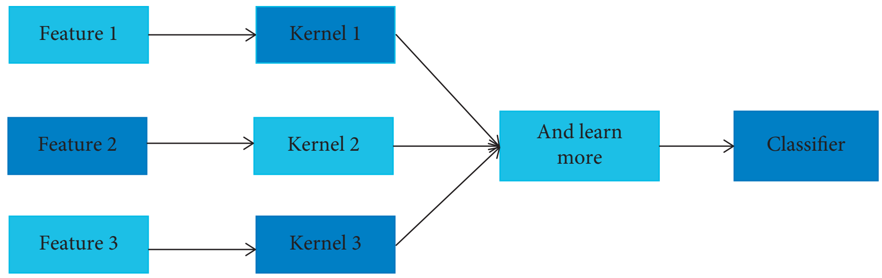

Figure 9: Schematic diagram of multicore learning feature fusion process.

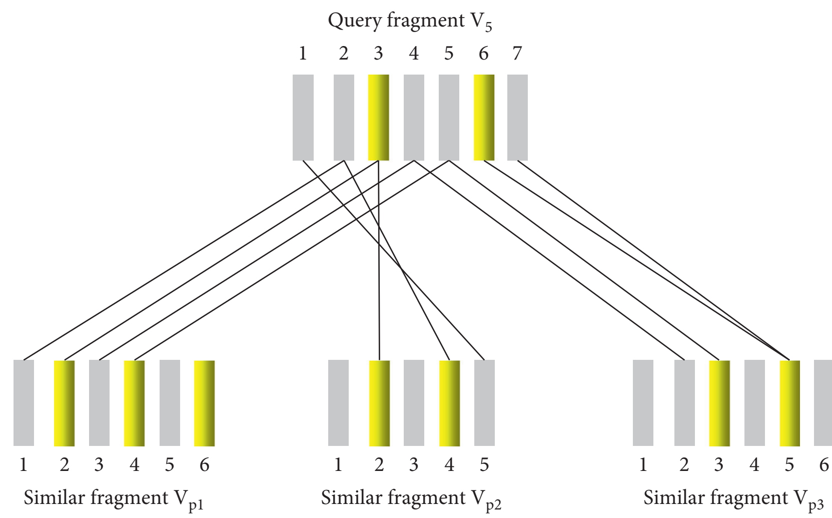

Figure 10: An example of video segment similarity matching.

where kg $(Xi) = [\text{kg}(Xi, X1), \ldots, \text{kg}(Xi, XP)]$, KF $(Xi) = [\text{KF}(Xi, X1), \ldots, \text{KF}(Xi, XP)]$, and km $(Xi) = [\text{km}(Xi, X1), \ldots$. According to the idea of simple MKL algorithm, the gradient descent algorithm is used to minimize the objective function and learn to solve the optimal parameters. The specific process is that, in each iteration, the classifier parameters α and B are calculated by giving the kernel function weight β; then, given α and B, a new kernel function weight β is calculated. Therefore, the classification function based on multicore learning support vector machine is as follows:

$$y = F(x) = \left[\sum_{g=1}^{G} \beta_g K_g(x) + \sum_{f=1}^{F} \beta_f K_f(x) + \sum_{m=1}^{M} \beta_m K_m(x)\right]\alpha + b. \quad (7)$$

In practical application, according to the content and structure characteristics of the video, comprehensively measure the above points and allocate the weight. Based on this, we can find the video clip with high similarity to the query clip.

5. Conclusions

The large amount of video data on the network is due to the wide range and fast speed of video transmission. The retrieval system improves precision and recall and has good practical performance, thanks to the density distribution, compactness, dispersion, and similarity between specific action segments in high-dynamic dance video. The diversity and repeatability of video become a difficult problem in the field of video retrieval when using content-based video retrieval. The related video retrieval research in this paper is focused on changeable dance videos. The single-layer method and hierarchical method are introduced first in terms of action recognition methods. Different actions must be fully detected in order to fully detect all types of actions, and it is preferable to cross at least once. When a video contains a variety of human actions, manually edit the video and then process it as if it contained only one type of action. Subaction sequences can be decomposed as high-level actions, and subactions can be decomposed as high-level actions until they are decomposed into atomic actions. As a result, motion recognition research has become increasingly popular in recent years, and it is now widely used in a variety of fields such as intelligent monitoring, human-computer interaction, and virtual reality. In a nutshell, human motion recognition research, particularly complex movement research, is still in its infancy, and many aspects such as methods and real time need to be improved. Despite the fact that an increasing number of researchers are working on this project, ongoing efforts are required to achieve the goal of advanced intelligent recognition and detection.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Data-Driven Learning Teaching Model of College English Based on Mega Data Analysis

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With the arrival of the mega data era, CET has developed a new teaching model based on mega data. This teaching requirement is met by a data-driven model based on mega data. By applying it to CET, students will be guided to explore and discover language rules and pragmatic features through quantitative analysis of data-driven technology, which will help compensate for the disadvantages of traditional English teaching and improve students' autonomous learning ability. The concept of data-driven language learning is introduced into teaching in this paper. Corpus is tried to stimulate students' autonomous learning in the teaching process, and the independent learning model of students is further improved in the teaching reform, based on educational theories of corpus linguistics and second language acquisition linguistics. Students' scores have improved, particularly in English listening, according to the findings. The data-driven CET-4 model improves students' learning ability and interest, as well as their ability to think creatively and critically.

1. Introduction

The advancement of computer and network technology has influenced not only people's daily lives but also traditional teaching methods, resulting in fundamental changes in people's methods and means of acquiring knowledge [1]. The deep integration of the Internet and IT has ushered in a new era of mega data, which presents both an opportunity and a challenge for current foreign language instruction. The teaching model has also undergone qualitative changes as a result of the inclusion of scientific and technological elements [2]. English instruction has progressed from a single computer-assisted method to a mixed method based on the Internet and derived mega data [3]. Learning resources, learning objectives, learning contents, and learning tools have all changed dramatically in the college English curriculum as a result of the digital and networked system [4]. People from all walks of life are becoming increasingly aware that whoever can take the lead in realizing mega data and who has a deeper understanding of mega data mining and application will seize the opportunity in the future. In the field of education, the penetration of massive data will inevitably lead to a high level of technological integration in the classroom. Developing smart classrooms, implementing data-driven learning (DDL) as a teaching model, and providing accurate decision-making will undoubtedly become a new trend in the future development of educational informatization, with a significant impact on profound changes in the field of education [5]. Under the tide of mega data, the DDL teaching mode method model, the DDL teaching mode method framework, and the practice of DDL teaching model are constantly emerging. The DDL teaching model has become an index to evaluate the effectiveness of any given teaching method [6].

The development of mega data technology provides new opportunities for the development of education and endows DDL teaching model with new connotations and missions. The wide application of data mining has brought rapid development to all fields of social life [7]. DDL model came into being in this situation and soon attracted people's attention, which will promote the development of foreign language teaching [8]. Applying it to college English teaching (CET) can create a real linguistic context for students and guide students to explore and discover language rules and pragmatic features through quantitative analysis of data-driven technology, so as to make up for the disadvantages of traditional English teaching model and improve students' autonomous learning ability [9]. DDL teaching model can improve our teaching efficiency and ensure our teaching quality. For the education industry, mega data is a major opportunity for traditional education research to move towards scientific demonstration. College English courses should use advanced IT to carry out English teaching based on computer and network so as to provide students with a good language learning environment and learning conditions [10]. This paper introduces the concept of data-driven language learning into teaching, based on the educational theory of corpus linguistics and second language acquisition linguistics; tries to use the corpus to stimulate students' autonomous learning in the teaching process; and further improves students' autonomous learning model in the teaching reform.

Through quantitative analysis of data-driven technology, it can be applied to CET to create a real linguistic context for students and guide them to explore and discover language rules and pragmatic features, thereby compensating for the disadvantages of traditional English teaching models and improving students' autonomous learning ability [11]. The corpus' rich and authentic corpus, as well as teachers' active assistance, not only stimulate English learners' interest in learning and cultivate their ability of active exploration, analysis, and induction but also greatly activate learners' innate language intuition and improve their cognitive and metacognitive skills [12]. The DDL method is a corpus-based discovery method for learning a foreign language that transforms the teaching space from closed to open. Learners are independent builders of knowledge, and the learning process is a knowledge construction process of self-creation and self-motivation. The DDL model, which is based on an English-driven decision-making model, has significant value and significance in encouraging empirical English teaching [13].

2. Related Works

Literature [14] points out that the most remarkable feature of DDL is that teachers do not know what rules learners will find in advance. DDL model is to enable English learners to actively explore the rules contained in the English corpus by analyzing the real and abundant data of the English corpus and to produce top-down discovery learning so as to cultivate English learners' autonomous learning ability. Literature [15] divides the research object into the control group and the experimental group. The experimental group adopts the DDL model for teaching, while the control group adopts the traditional way of teaching by teachers. Through pre-test, post-test and qualitative research, it is finally found that using DDL model for vocabulary learning is far better than the traditional teaching model. Corpus is widely recognized in language teaching, especially that language learning should be based on the abundant corpus. Therefore, the corpus-based DDL model becomes the best choice for teachers. Literature [16] indicates that DDL model is still more effective than the traditional language teaching method for language learners who have not received corpus operation training and primary level. In addition, it is far more beneficial to use keywords in a real and rich linguistic context for teaching than a long context composed of one or more sentences. Literature [17] shows that paper-based materials can eliminate the obstacles encountered in using corpus-based DDL model and make DDL model win more followers. This is because language learners at the primary level and those with lower qualifications do not have enough prior knowledge and patterns to follow, so they cannot learn effectively from a purely inductive teaching pattern. Literature [18, 19] holds that the transformation from DDL to demand-driven corpus should be completed. However, the DDL model cannot fully assume how to grasp the actual needs of learners. Literature [20] holds that the previous corpus-based DDL research ignored the differences of learners in the learning process. That is to say, the corpus-based DDL model only pays attention to the integrity of learners and ignores the particularity of learners.

The abundant corpus provided by the corpus can make up for the deficiency of the existing English textbooks to a certain extent and enrich the process of English teaching in form and meaning. At present, the application of the DDL model in teaching English to speakers of other languages is mostly limited to theoretical discussion but lacks systematic empirical investigation and research. Taking CET as an example, this paper studies the DDL teaching model of college English under the background of educational mega data and analyzes the operation process of this model.

3. Present Situation of CET

Although China's CET has been reformed in many aspects, the traditional classroom teaching model is still being followed, whether it is college English textbooks, teaching contents, or tests at all levels, including CET-4 and CET-6. Students rely more on vocabulary accumulation and grammar knowledge, focusing on various tests, rather than on the practice of communication in the real context. The combination of the corpus with computer and network makes its application in CET show us a new platform. In addition, corpus linguistics also plays an important role in foreign language teaching theory, content, and methods.

Our era is experiencing an information explosion due to the rapid development of the Internet and the emergence of cloud computing. The teaching model has also changed qualitatively as a result of the inclusion of science and technology elements. English teaching has progressed from a single computer-assisted method to a mixed method based on the Internet and mega data derived from it in the past. Corpus linguistics is a science of language analysis and research based on real corpora [21]. It is devoted to text retrieval, sampling, analysis, and statistics. The introduction of corpus linguistics into CET can merely compensate for the aforementioned flaws. Corpus linguistics has become increasingly linked to foreign language teaching as computers have advanced. The human-computer interaction-centered organization of classroom teaching is now the focus of the

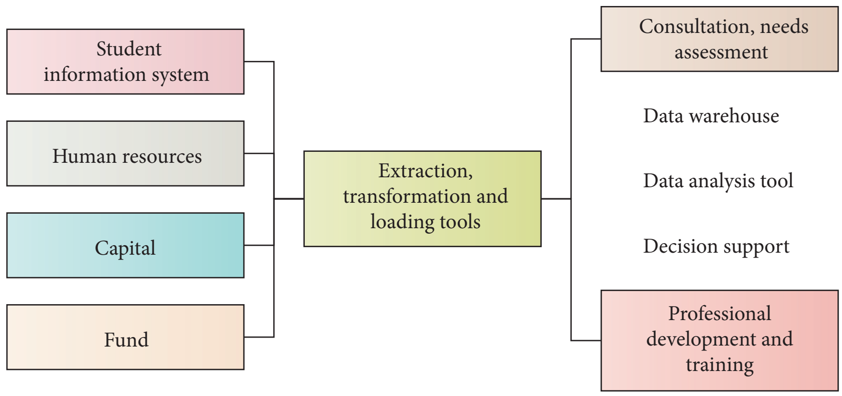

Figure 1: Data-driven decision model.

corpus-based data-driven CET model. After the teacher has compiled the language materials on the computer, students can read the materials on the computer and engage in student-centered learning. This model is only appropriate for the core educational viewpoint of today's college English reform, namely, the autonomous learning education model.

4. Construction of English-Driven Decision Model

4.1. Generation of Data-Driven Decision Model. Corpus is a new type of learning resource; it is essentially a warehouse for storing language materials, where many natural language materials of spoken and written languages are gathered. Corpus is a large-scale collection of written and spoken natural language materials that serve as a warehouse for storing language materials, also known as a language database. Because of the advancement and application of computers, the corpora we now use are essentially electronic corpora, which store a large number of language materials in the form of text via computers. The emergence of corpora provides more advanced technical means for linguistic research, as well as significant shifts in language research thought [22]. Knowledge acquisition, according to constructivism, is not a one-time event, and learners' social and cultural backgrounds and situations play a significant role in constructing the meaning of what they have learned. Learners are cognitive subjects, not passive recipients of knowledge. Learners benefit from learning in real or near-real situations because it allows them to explore the world based on prior experience and to build new knowledge on top of previous knowledge.

With the development of data mining technology, it is possible to make decisions by using various data analyses, which also enables the emergence and development of data-driven systems. The data-driven decision model is shown in Figure 1.

The learning process in DDL model is divided into three stages: pointing out problems, classifying materials, and summarizing. The target language in learning can be summarized as the process of data-driven language learning. Learners classify and search the corpus for context cooccurrence in order to collect a large amount of real information, which they then input into the materials for induction and summary in order to obtain the law of language. The following aspects of the corpus can be roughly summarized: systematicness, authenticity, flexibility, representativeness, and richness, among others. These characteristics help foreign language learners create complex and realistic task scenarios, which not only help them master more basic language skills but also boost their learning enthusiasm and initiative. The autonomous learning of students dominates the learning process [23]. Teachers typically serve as a guide, organizer, and negotiator in this process, assisting students in determining the overall learning direction. While students are the driving force behind the learning process, they must manage, monitor, and evaluate themselves, as well as further develop their autonomous learning ability, which can have a positive impact on other aspects of students' lives, forming a virtuous circle and promoting learning.

Language learning under corpus DDL model is the concrete practice of the core content of constructivism theory. With the increasingly mature corpus retrieval tools as the means, it observes and analyzes a large number of real language phenomena by learners themselves or in collaboration with others and sums up their language rules by combining the old information in their minds so as to realize the internalization of knowledge. Sustainability is used to measure the sustainability standard of quality evaluation reform and transformation system and the progress of each subsystem. The development speed of each subsystem is used as a measure as follows:

$$w = \left(w_{\max} - w_{\min}\right) \times \frac{I_{\max} - I_i}{I_{\max}} + w_{\min}. \tag{1}$$

Use clustering algorithm function method to find

$$Cr_{(t+1)} = k \times Cr_{(t)} \times \left(1 - Cr_{(t)}\right). \tag{2}$$

The calculated trend degree is as follows:

$$f_1(x) = \sum_{i=1}^{D-1} \left[100\left(x_{i+1} - x_i^2\right)^2 + \left(x_i - 1\right)^2\right]. \tag{3}$$

Large corpora have evolved into shared resources, with some corpus retrieval software available for download and

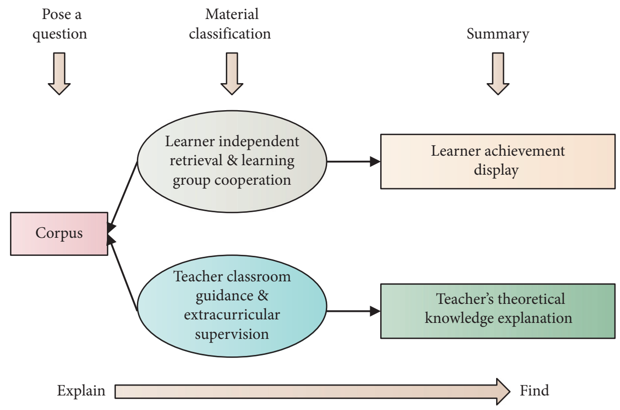

Figure 2: College English classroom teaching under the corpus DDL model.

use on computers. All of this provides a research foundation for implementing and developing DDL in foreign language instruction. DDL is a corpus-based language teaching model. Students' exposure to real language is generally limited in traditional teaching models, and the input of a large number of non-authentic languages causes various language errors, which has been fully verified in teaching practice. This is a problem that DDL excels at [24]. This is because all of the language data sources provided by the corpus for students are real communication activities, and they help students improve their language intuition and master a more pure language by creating a real linguistic context for them.

4.2. Construction of English-Driven Decision Model. The education industry has undergone significant changes and innovations as a result of the development of the Internet. The methods used to teach English are varied and innovative. Sources of teaching materials are becoming more diverse. Students and teachers can look up words on the Internet using online dictionaries, as well as use shared teaching resources created by other students. Teachers and students can use the Internet to discuss problems in the classroom and do supplementary learning after class by forming English learning groups or using the teaching platform. On the network platform, teaching is no longer limited to the classroom; it can now take place at any time and in any location. Teachers' lessons to students may be partially or completely uninteresting. This raises an important issue, namely, perception misalignment. As a result, perceived mismatch may be an important factor in causing unsatisfactory teaching results in second language teaching. Because of the traditional teaching model, the DDL model is no exception, and learner analysis is more influenced by test scores. Even though it involves a thorough examination of students' needs, motivations, and preferences, it is primarily based on teachers' intuition and experience. Learners' basic information, learners' learning motivation, learning preferences and needs, learners' vocabulary and grammar learning strategies, perceived mismatch between teachers and students, and teachers' beliefs are all sources of data in the English-driven decision-making system.

Teachers' beliefs largely determine the success of classroom teaching. Obviously, the DDL model based on the English-driven decision-making model not only takes into account learners' factors but also recognizes the importance of teachers' beliefs and perceived mismatch between teachers and students for data collection and analysis. Corpus DDL model of college English classroom teaching is shown in Figure 2.

Before using the DDL model for teaching English to speakers of other languages, in order to ensure the teaching effect, all factors that may affect the teaching process must be collected from learners' learning motivation, learning preferences, learning needs, teachers' beliefs, and learning strategies. The English-driven decision model is shown in Figure 3.

Students participate in the establishment of key and difficult points in the classroom through study groups, conduct corpus retrieval analysis on the problems discovered or to be solved, observe the retrieval results, discuss in groups, and present the discussion results in the classroom. The English-driven decision-making model incorporates basic learner information, and its foundation is a better understanding of learner characteristics. Differences in thinking and cultural beliefs, for example, caused by differences in nationalization, have a significant impact on learners' learning activities. Students and teachers are confronted with a plethora of data. How can science and technology be used to screen these data and determine their practical value? It's a problem that both teachers and students must work together to solve [25]. The fundamental premise of using the DDL model in English teaching is to analyze the learning needs of English learners. When analyzing the learning needs of English learners, we must take into account the learners' complex expectations and contradictions, as well as the language and cultural needs of the learners. In order to create more targeted teaching materials that meet the needs of students.

Positive indicators, then

$$X'_{ij} = \frac{\left[\max\left(X_j\right) - X_{ij}\right]}{\left(\max\left\{X_j\right\} - \min\left\{X_j\right\}\right)}. \tag{4}$$

Inverse indicators, then

$$X'_{ij} = \frac{\left[X_{ij} - \min\left(X_j\right)\right]}{\left(\max\left\{X_j\right\} - \min\left\{X_j\right\}\right)}. \tag{5}$$

In order to ensure that the logarithmic calculation is meaningful when calculating the entropy value, all the data is shifted by 0.5, $Y_{ij} = X'_{ij} + 0.5$, $Y_{ij} \in [0.5, 1.5]$, and the shifted value is subjected to a proportional transformation to obtain the normalized value of each evaluation index. The proportional transformation formula is as follows:

$$Z_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{m} Y_{ij}}. \tag{6}$$

Teacher's input means that teachers subconsciously think that this is what learners should learn and master in

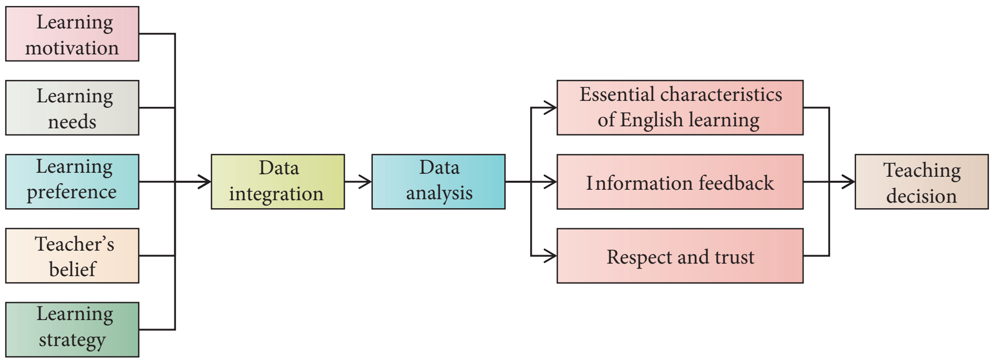

FIGURE 3: English-driven decision-making model.

this class by providing oral and written language materials or other forms of information. Learner acquisition refers to what learners get through personal participation or other learning methods in the course of the class, not just the ready-made information provided by language materials. In the multimedia classroom, teachers and students can experience this classroom teaching model together. However, attention should be paid to the proportion of online classrooms in the whole teaching system and the arrangement of class hours, which not only makes an attempt of classroom reform but also does not affect the normal learning progress of students.

5. Result Analysis and Discussion

It is the main carrier of language, and it is contained in culture, and culture is embodied in language. From the perspective of human beings, it is emphasized that the essence of culture is closely related to the essence of human beings. Culture fundamentally distinguishes human beings from animals, and the essence of culture is creation. Keyword list can be regarded as a common vocabulary or core word group that students often use to express a certain topic. This core word group is associated with other keywords in the thesaurus. Students have reduced semantic differences in the use of words. That is, some words sharing some semantic features are used alternately to express the same concept. This feature makes the students' vocabulary use focus on a few limited core words, and the concepts expressed are monotonous and vague.

Students may not have enough knowledge or confidence in words with more specific meanings, so they use words with broader meanings instead. When students use some fixed or semi-fixed collocations, their choice of collocations is free and changeable, unlike native English speakers, which have certain restrictions [26]. Therefore, to learn and use a foreign language, we must understand the culture closely related to the foreign language, and familiarity with the relevant culture is conducive to using a foreign language appropriately. A learning method that takes words or phrases as a unit and focuses on the sensory memory stage of memory is convenient for students to process vocabulary at a shallow level and memorize vocabulary. Select a number of students to test and compare the memory effect with that of traditional methods, as shown in Figure 4.

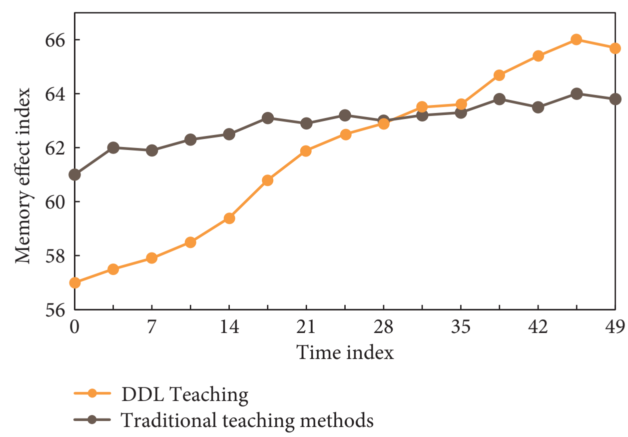

FIGURE 4: Comparison of memory methods.

Students' strong desire to pay attention to society and sense of participation is in sharp contrast with their vague understanding of social modeling. In the expression of students' theme, campus and society are divided into compulsory binary parts so that they can form semantic opposition in the use of words. Teachers should explain the teaching objectives and tasks of this class in class and at the same time conscientiously implement the teaching according to the teaching plan and lesson plan [27].

Set the related parameters of English learning resources distribution, reconstruct the constraint parameters of English learning ability evaluation, and get the time-domain curve of distribution as shown in Figure 5.

Teaching a language is a step-by-step process that progresses from simple to complex. As a result, the teaching of English culture should be done in stages and according to the principle of step by step. The content of culture instruction is determined by the students' language level, acceptance ability, and comprehension ability. Teaching should go from the easy to the difficult, from the simple to the complex, and from the phenomenon to the essence. Teachers should assist poor students in comprehending the cultural information provided by the text itself rather than introducing foreign content [28]. Within the same region, there are linguistic differences. Language has an impact on culture and can also be used to learn how to express culture.

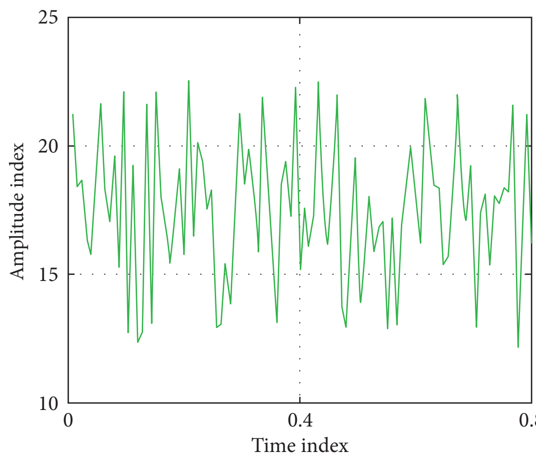

Figure 5: Time-domain distribution curve of mega data.

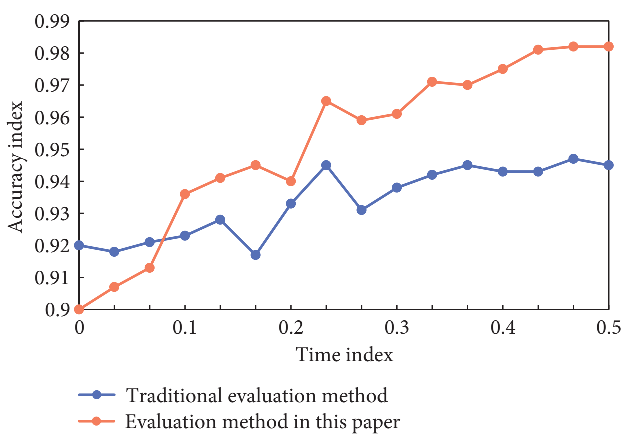

Figure 6: Comparison of accuracy data of two analysis methods.

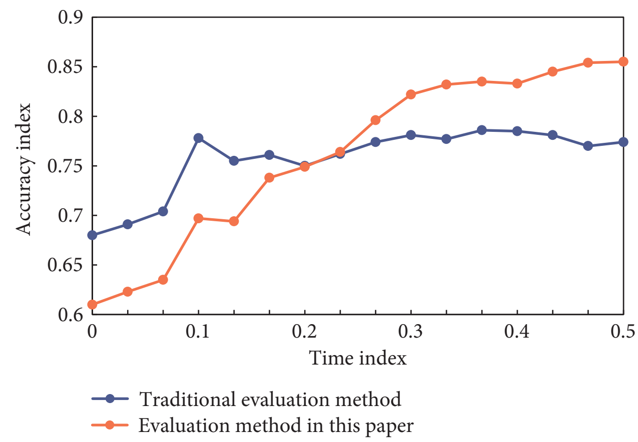

Figure 7: Comparison of utilization data of two analysis methods.

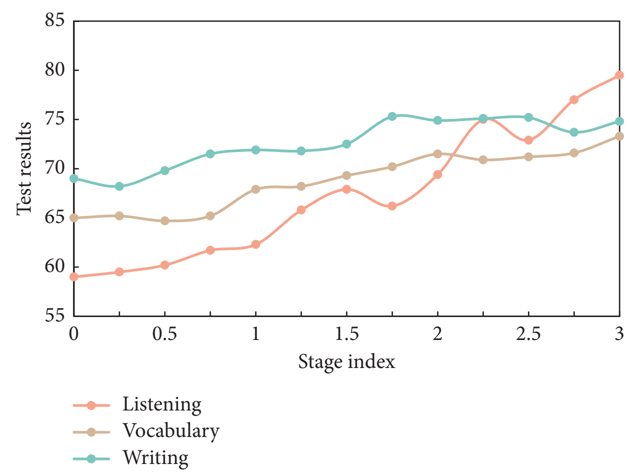

Figure 8: Comparison of achievements.

The accuracy of learning ability evaluation with this method is high, and the utilization rate of learning resources is good. A comparison of the two analysis methods is shown in Figures 6 and 7.

Language is not only a way of human communication but also a means of guiding the speaker's views. It provides people with idiomatic patterns for analyzing reality. Cultivating cross-cultural awareness in English teaching can better conform to the trend of globalization, so we must do this link well. The success of students' word use depends on whether they can build a word network around a theme, association, and word collocation. Its significance lies in that foreign language teaching, especially English teaching, centered on a certain topic and semantic association may be more effective than isolated and discrete vocabulary learning. If teachers do not care about the actual situation of students and the content of teaching materials, they will instill cultural knowledge into students, which is unacceptable to students with low English levels. Cultural diversity leads to linguistic diversity. Cultural differences are not only reflected in different regions. Many cultures will change with the passage of time and the influence of other cultures.

Using DDL model in English vocabulary and grammar teaching reflects the complexity of corpus retrieval, the diversity of corpus content, the dynamics of corpus selection, and the difficulty and time consumption of corpus analysis and collation. It also reflects the dynamics of learners' learning motivation, the complexity of cognitive strategies, the nonlinearity, and self-organization in the learning process. Learners' learning in DDL model, from curiosity and excitement at the beginning to joy at the middle stage to negative emotions at the later stage, fully shows that learners' learning motivation has changed. The test results are shown in Figure 8.

Students' scores have improved, particularly in English listening, according to the findings. There is a pedigree relationship between words when a person uses words to express his understanding of the real world. The semantic space is at the top of this hierarchical relationship. Language learners struggle to match the semantic field of their mother tongue to the semantic field of the target language. The learner's task is to match the mother tongue's semantic field to that of the second language. What they do not realize is that a second language semantic concept is realized as a word [29]. It may, however, be realized in its mother tongue as multiple words, or it may not be realized at all, or it may only be realized as mother tongue through difficult translation and interpretation. Different cultures are reflected in different languages. Language causes people to think and express themselves in a variety of ways. As a result, people act in different ways. There will be differences, while the globalization of education and the local foundation have an impact. Different thesaurus groups are divided according to semantic functions, and the statistical key thesaurus and thesaurus are grouped and analyzed according to composition topics. By connecting the analysis results with the composition topic and drawing, we can directly observe the basic words used by students to express a certain topic, as well as the relationship between these words.

6. Conclusions

Each teacher has his or her own approach to teaching, and each student has his or her own study habits. This personalized design is made possible by big data. Teachers can select their own teaching materials and develop their own teaching style. Teachers can pay close attention to each student's microscopic performance based on the data and adjust the education plan accordingly through the analysis of relevant student data, resulting in personalized education. With the help of abundant corpus materials and data-driven teaching methods, the corpus-based DDL teaching model of college English can effectively improve teachers' teaching level and students' autonomous learning ability, thus effectively improving the CET effect. The data-driven CET model improves students' learning ability and interest, as well as their ability to think creatively and critically. Students' overall scores have improved as a result of the new learning evaluation system. Students have a strong interest in learning physical education courses as a result of its implementation, and the new learning evaluation system has a positive impact on students' learning. This effect will be further enhanced if teachers can select and build a corpus of appropriate scale and suitable for students in our school from the actual level of students in our school and then carry out teaching activities on this basis.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Intelligent Analysis on the Rationalization of Children's Physical Education Curriculum Based on Recurrent Neural Networks

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In the future, the majority of PE (physical education) students in regular schools will become preschool teachers. As a result, these students' sports habits and feelings will have a direct impact on future preschool education and the training of preschool children's sports habits. As a result, PE curriculum in preschool normal schools must adapt to the future development of preschool education. This article develops a scientific, reasonable, and valuable children's PE curriculum by constructing the basic framework of modern children's PE curriculum. As a result, this research proposes two RNN-based models: one is a personalized recommendation model for children's PE curriculum—LSAPR (long short-attention point-of-interest recommendation) model, and the other is a recommendation model for children's PE curriculum sequence LSTM-RNNSR (long- and short-term memory-RNN sequence recommendation). The two models proposed in this paper have produced good off-line experimental results in various datasets, as well as a real-time personalized point-of-interest recommendation effect in practice.

1. Introduction

Children's sports have gradually become the focus of education practitioners, parents, and society in China, thanks to the Sunshine Sports Project's multilevel and all-around development [1]. The development of preschool education is directly influenced by the quality of preschool education. As a result, reforming the PE curriculum in preschool normal schools and improving students' attitudes toward physical activity are critical for exporting qualified preschool teachers, cultivating talents in line with social development, and improving preschool education quality.

At present, the research on curriculum teaching reform in general higher vocational colleges has changed from the traditional focus on technology, and teaching methods and means to all-round and multilevel research on teaching reform, such as teaching material construction, teacher team construction, teaching idea renewal, teaching mode, teaching organization form, teaching content, and teaching environment. [2] For example, some scholars have performed research on the reform of professional teaching in PE colleges; some scholars have performed research on fitness value development and other related aspects from their own point of view [3, 4]. Literature [5] writes that it is necessary to cater to students' main needs, create problem situations, stimulate students' interest in inquiry, and experience the happiness brought by success, thus breaking the competitive sports teaching mode that ignores students' psychological experience, changing the traditional organization mode, and closely combining school sports with social sports activity groups. Literature [6] found that the current mode of PE (physical education) courses in universities is mostly "three-stage," that is, the first-year basic PE class, the second-year optional courses, and the third-year and above elective courses. Literature [7, 8] makes a survey of the most popular sports among students in five universities, including table tennis, football, basketball, badminton aerobics, volleyball, and swimming. The results show that among the most popular sports in the universities surveyed, football actually ranks last, and the situation is not optimistic.

Preschool normal education in China has developed rapidly as the education system reform has progressed, and the educational concept and talent training mode of preschool normal education have changed dramatically, and the educational mode is becoming increasingly diversified [9]. However, there are still many issues to be resolved in terms of teaching mode and content in actual teaching. This study uses RNN (recurrent neural network) to assist and educate preschool teachers, develop more effective and sustainable preschool PE curriculum ideas, establish successful curriculum models, and provide high-quality educational services for young children.

At present, in the establishment of a teaching system, the school has established the PE teaching target system, which focuses on lifelong PE, supplemented by healthy PE and sports skills learning. However, it seldom involves the direction of sports culture shaping and sports appreciation, and the teaching evaluation methods are different. Therefore, this article applies the RNN model to the analysis of rationalization of preschool PE curriculum.

2. Related Work

DL (deep learning) usually uses the artificial neural network to learn the high-level data representation. By learning the depth model of a large amount of data, high-level data representations can be extracted from lower levels. For example, literature [10] proposed a method of processing a song as a group of 599 consecutive frames and trained CNN (convolutional neural network) [11, 12] to learn its sentences to solve the cold start problem in recommendation. Literature [13] proposed that the CNN (convolutional neural network) integrates product description into probability matrix decomposition. Compared with the topic model, it can capture context information of text. Because the size of convolution kernel is fixed during CNN training, the CNN with different convolution kernel sizes may be needed to improve the performance. A more common way to model text sequences is to use the RNN model.

Up to now, only a few recommendation methods based on the neural network have been proposed for POI (point-of-interest) recommendation, and the main network structure of these methods is the RNN structure and its variants. Literature [14–16] point out that both short-term preferences and long-term preferences of users cannot be ignored, but the traditional RNN structure is not designed to distinguish these two preferences at the same time. The popularization of literature [17] has brought some successful practices of model-based methods, which are based on MF (matrix factorization) technology. Literature [18] combines social influence with CF (collaborative filtering) model based on users and uses the Bayesian model to model geographical location context. Literature [19] shows how inner product linearly combines with potential features and limits the expressive ability of MF. Literature [20] proposed a latent model based on tensor, which considered the influence of users' latent behavior patterns on the recommendation results. The pattern was determined by context time and category information. Literature [21] uses the RNN to predict the click of online advertisements. At every moment, they train the RNN with the latest click of users and the previous state of the network and use the classification loss measure (cross-entropy loss) to predict the next click of users. Literature [22] proposes a context-adaptive method for constructing session-aware recommenders, which can deal with long-term (e.g., seasonal) and short-term changes of user preferences in the news field. In their work, the author put forward a semantic structural model of time depth, which combines the characteristics of users and projects with the characteristics of users' time into a joint model, in which the static characteristics are modeled by several feedforward neural networks and the time characteristics are modeled by a group of RNN.

3. Research Method

3.1. Curriculum Structure of Preschool PE. The definition of children's PE can be divided into different levels from a social standpoint. In a broad sense, it refers to children as the subject of sports activities, and in a more specific sense, it refers to the public's perception of kindergarten PE. Children's PE should follow the rules of children's growth and development, improve health, systematically teach children sports, health care, and a healthy lifestyle, cultivate children's interests and hobbies in sports, form the habit of exercising, and promote the all-round development of children's physical and mental personalities, according to this article. Curriculum development is a difficult and time-consuming task that encompasses not only the dominant curriculum idea, curriculum setting principles, and curriculum structure, but also the implementation and evaluation of curriculum. As a preschool teacher training institution, it is critical to establish clear training objectives, training modes, and principles for preschool teachers in today's society, as well as to train and adjust teachers' skills on a timely basis.

With the deepening of the educational system reform, the preschool normal education in China is developing rapidly. The educational concept and talent training mode of preschool normal education have been greatly improved, and the educational mode is becoming more and more diversified. However, in actual teaching, there are still \many problems to be solved in teaching mode and teaching content. In preschool normal PE, the ratio of male to female is seriously out of balance. If the teaching content of PE cannot be arranged reasonably. The teaching evaluation of PE is single, the evaluation method lacks scientificity, and the PE in preschool normal schools still focuses on physical quality assessment items, paying attention to the results and ignoring the differences of students' individual basis. This teaching mode lacks motivation and unfairness, which is not conducive to the development of quality education.

The theoretical basis of curriculum includes policy basis and academic basis. As a course, there must be a clear educational outline, including the requirements and indicators of educational tasks and objectives, educational principles, educational environment, and educational contents and methods. The basic framework of the course is shown in Figure 1.

There is explicit and implicit curriculum content in the curriculum. Explicit content in kindergartens refers to daily sports activities, whereas implicit content refers to material and spiritual content such as environmental creation, work

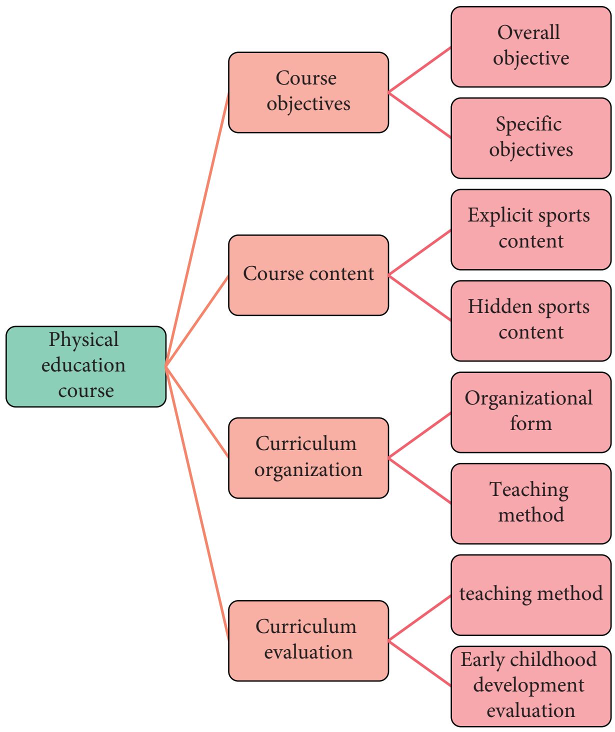

Figure 1: Basic framework of modern preschool PE curriculum.

and rest time, teacher-student relationships, good atmosphere, and home cooperation, among other things. The terms teaching methods and “teaching means” are used interchangeably. Individualized, group, and collective teaching methods are commonly used in preschool PE. Appropriate teaching methods and means should be used to improve children's interest in learning, taking into account the teaching objectives, children's abilities, and teaching resources.

3.2. Personalized POI Recommendation Model with AM. The formation of children's motor skills is the complementary connection of vision, hearing, vestibule, and other organs. Preschool teachers should use correct and graceful motor demonstration, and concise and neat oral instructions, and protect children in the teaching of difficult movements. It is difficult for children to fully understand and master what they have learned. Therefore, teachers require children to practice the actions they have learned repeatedly and attach importance to their active experience, independence, and innovation.

Among the means of curriculum evaluation, one is measurement-based evaluation, which aims at obtaining empirical data through strict measurement. The other kind of evaluation is based on speculation and logical inference, through rigorous analysis and demonstration at a higher theoretical level. Reveal the significance of the course and explain the value of the course. The evaluation of modern curriculum generally pays attention to the effective combination of the two.

In this chapter, an LSAPR (long short-attention point-of-interest recommendation) model is proposed, which uses all historical POISS of users to capture users' real long-term preferences and weights different times of the current POI sign-in sequence with AM (attention mechanism) [23].

RNN is a kind of artificial neural network modeled by sequence information. The structure of RNN is shown in Figure 2.

Specifically, given the sequence $x = (x_1, x_2, \ldots, x_T)$, the RNN updates the circular hidden state h_t by the following formula:

$$h_t = \begin{cases} 0, & t = 0, \\ \sigma(h_{t-1}, x_t), & t \neq 0, \end{cases} \tag{1}$$

where σ is a nonlinear function, such as tanh and sigmoid function.

Specifically, the hidden state update of the RNN in formula (1) is usually realized by the following formula:

$$h_t = g(Wx_t + Uh_{t-1}), \tag{2}$$

where g is a nonlinear function and W, U is a weight matrix.

An LSA algorithm using all user login sequences is proposed, which can dig out the user's long-term preferences from all the user's historical POISS (POI sign-in sequences) and pay attention to the short-term preferences in the current POISS. See the following formula for the specific forward propagation process:

$$\begin{aligned} \alpha_i &= Z_0 \sigma\left(Z_1 h_i^m + Z_2 h_t^m + Z_3 \overline{h}_t = b_\alpha\right), \\ h_{LSA}^m &= \sum_{i=1}^{t} \alpha_i h_i^m. \end{aligned} \tag{3}$$

Here, α_i represents the weight of the i th moment in the current POISS; h_{LSA}^m is the attention representation of the current POISS obtained by the AM; h_i^m indicates that the hidden state of the first moment in the current POISS represents the overall representation of the current POISS; h_t^m represents the user's long-term preference; and Z_*, b_α is the weight matrix and the deviation vector, respectively.

This article introduces the LSA mentioned above into the decoder of CAPR (context-aware point-of-interest recommendation), which can mine users' long-term preferences from all historical POISSs of users. Figure 3 is a schematic diagram of the network structure of LSAPR.

In this article, the general GRU structure is extended, the context information is integrated into the gating structure, and a CAGRU (context-aware gated recurrent unit) is proposed. Based on the natural geographical location attribute, time point attribute, and category information of POI, this expansion can make GRU structure more suitable for POI recommendation tasks.

It can be seen from Figure 3 that the LSAPR model first inputs the user's historical POISS into the CAGRU encoder to encode the whole sequence and at the same time uses the CAGRU. The encoder obtains the hidden state of each moment of the current sequence of the user. Then, input

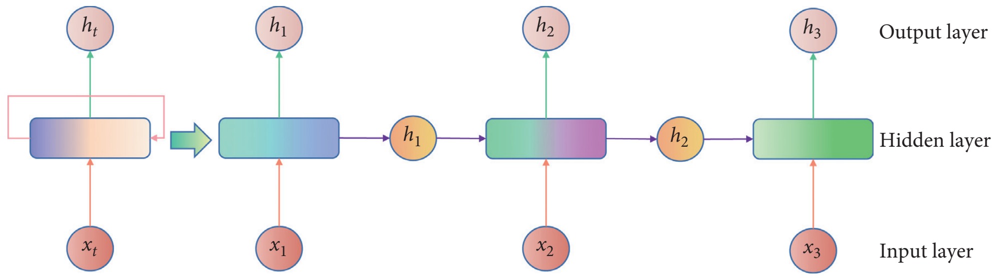

FIGURE 2: RNN structure diagram.

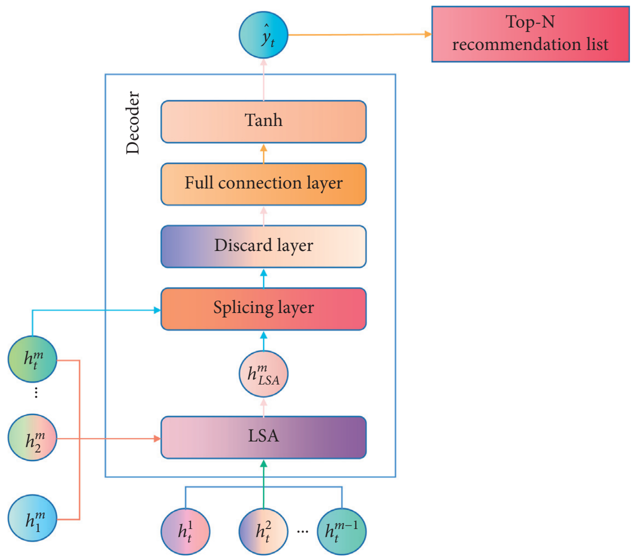

FIGURE 3: Schematic diagram of the LSAPR model structure.

these data into LSA to obtain the attention expression of the current POISS, which is given as

$$h^m_{LSA} = LSA\left(\left\{h^1_t, h^2_t, \ldots, h^{m-1}_t\right\}, \left\{h^m_1, h^m_2, \ldots, h^m_t\right\}\right). \quad (4)$$

It is necessary to train the data of each user separately during the LSAPR model training process in order to obtain personalized recommendation results for that user. Each user's POISS is sorted by starting time and then divided using the subsequence division method described in CAPR model training. To speed up the calculation of the attention score, the entire representation of the sequence before it is stored in memory for each POISS.

3.3. Sequence Recommendation Model Based on RNN. The learning evaluation system for PE courses in ordinary schools, as an important part of PE, lags behind in terms of reform and does not fully reflect its inherent function of guiding and encouraging people to grow up healthy and harmoniously. The goal of improving and perfecting the PE teaching content, teaching mode, and evaluation system is to meet the needs of society and comply with relevant requirements and norms, with the ultimate goal of "cultivating students' lifelong sports habits" and the specific goal of "enhancing students' physique, improving students' enthusiasm for participating in sports activities, and promoting students' physical and mental health development."

Today, with the increasingly severe social competition, the training objectives of school education are becoming more and more clear. How to make these technical applied talents who are fighting in the front line of society have good physical qualities and put them into the construction of society will become the development focus and development trend of school PE.

In this article, a new recommendation model LSTM-RNNSR (long- and short-term memory-RNN sequence recommendation) is proposed. The model consists of RNN attention module and item-item relationship module, which is integrated with the matrix decomposition model and optimized by Bayesian personalized sorting.

LSTM (long- and short-term memory) introduces gating mechanisms such as forgetting gate and input gate [24], which better solves the problem of gradient disappearance or explosion, so the LSTM-based model is widely used for text modeling, especially for long text modeling.

There are three gates in the LSTM unit to protect and control the state flow. For each time step t, given the input x_t and the current cell state c_t, the hidden state h_t can be updated with the previous cell state c_{t-1} and the hidden state h_{t-1}, and the update formula is as follows:

$$\begin{bmatrix} i_t \\ f_t \\ o_t \end{bmatrix} = \begin{bmatrix} \sigma \\ \sigma \\ \sigma \end{bmatrix} \left(W\left[h_{t-1}; x_t\right] + b\right),$$
$$\widehat{c}_t = \tan h\left(W\left[h_{t-1}; x_t\right] + b_c\right),$$
$$c_t = f_t \otimes \widehat{c}_{t-1} + i_t \otimes \widehat{c}_t,$$
$$h_t = o_t \otimes \tan h\left(c_t\right). \tag{5}$$

Here, i_t, f_t, o_t are the input gate, the forgetting gate, and the output gate, respectively, and the value range is $[0,1]$, σ is the sigmoid function, and $\otimes$ represents the element multiplication. The hidden state h_t represents the output information of the LSTM unit at time step t.

Because closely related project pairs may appear in L, T at the same time, different from previous studies, this article applies inner product between input item embedding and output item embedding to capture the item relationship between L, T:

$$\sum_{e_i \in S_{u,l}} e_i^T \cdot Q, \tag{6}$$

where $Q \in R^{d\times N}$ is the output item embedding, and the sum of inner product results captures the cumulative item-item relationship scores from each item in L to all other items.

Because the training data come from implicit feedback from users, this article optimizes the proposed model through Bayesian personalized sorting:

$$\arg\min \sum_{\left(u,L_u,i,k\right)\in D} -\log\, \sigma\left(\widehat{r}_{u,i} - \widehat{r}_{u,k}\right) + \Omega. \tag{7}$$

Here, L_u represents the continuous term of a user u in $|L|$, k represents the negative term of random sampling, and Ω is the regularization term to prevent overfitting. By minimizing the objective function, the partial derivatives of all parameters can be calculated by back propagation and gradient descent. At the same time, the Adam optimizer is used to automatically adjust the learning rate in the process of model learning.

Therefore, the PE teaching in preschool normal schools should constantly update the teaching content, so that students can lay a good foundation of knowledge. In teaching practice, it is necessary to provide students with opportunities for in-depth preschool education activities and practice, so that they have stronger social adaptability and at the same time can also integrate theory with practice and continuously improve their theoretical level in practice. In addition, the PE curriculum in preschool normal schools should reflect the characteristics of the school, add special courses in combination with the nature, characteristics, conditions, and personnel training objectives of the school, and provide more choices of courses to meet the diversified needs of students' future development.

4. Results Analysis and Discussion

4.1. Theoretical Results and Analysis. Following visits to and consultations with several schools, eight of the ten schools surveyed have developed their own PE curriculum in accordance with the National General Universities PE Teaching Guidelines, and some preschool normal schools have developed their own curriculum in accordance with their own operating conditions and actual teaching situation. Figure 4 depicts the statistical results of the selected public curriculum questionnaire in PE class.

The curriculum of the old syllabus finally determined by the questionnaire is basketball, gymnastics, track and field, volleyball, and so on. The final curriculum of the new syllabus is basketball, badminton, table tennis, yoga, physical training, sports theory, theoretical investigation, swimming, sports dance, gymnastics, track and field, and soft volleyball. The statistical results of the questionnaire selected for the test index of students' physical quality in preschool schools are shown in Figure 5.

The final test methods of students' physical fitness determined by the questionnaire are 30-meter run, shot put in place, shot put back, bench push, squat, and standing long jump.

Teachers must devise sports games and thoroughly explain the rules to children in accordance with the syllabus's requirements. Teachers only need to explain and emphasize the scope of the children's activities and the game rules when playing games. Teachers must re-explain the content of their lessons and determine the most effective teaching techniques. Recognize the parts that are difficult for children to master on a technical level. Children have already gained active experience and a new understanding of the teaching content as a result of this process. Teachers should also pay close attention to the standardization and details of the experience process, and set higher expectations for the children. Observe the children's experiences as bystanders and make a note of the characteristics of a few of the observations. For example, if a teacher needs to get closer to the students, he can squat and pass on the content of the lesson to the students.

4.2. Analysis of Personalized POI Recommendation Model of Preschool PE Curriculum. In order to accurately evaluate the performance of each model in POI recommendation tasks, this article adopts two evaluation indexes, Recall@K (recall rate) and MRR @ k (mean recall rank), which are widely used in recommendation systems. k represents the length of the recommendation list. In order to accurately evaluate the influence of different list lengths on recommendation results, this article selects the values of each evaluation index when the lengths of the report list are 2, 6, and 10.

In order to determine the appropriate hidden state dimension of the CAGRU structure in the model, this article uses the training set and the verification set to select the hidden state dimension parameters of the two models under the same other parameters. Take the experiment of CAPR model on Foursquare dataset as an example, and the results are shown in Figures 6 and 7.

It can be seen that with the increase in the hidden state dimension, the performance of the model gradually gets better, but under the condition that the number of

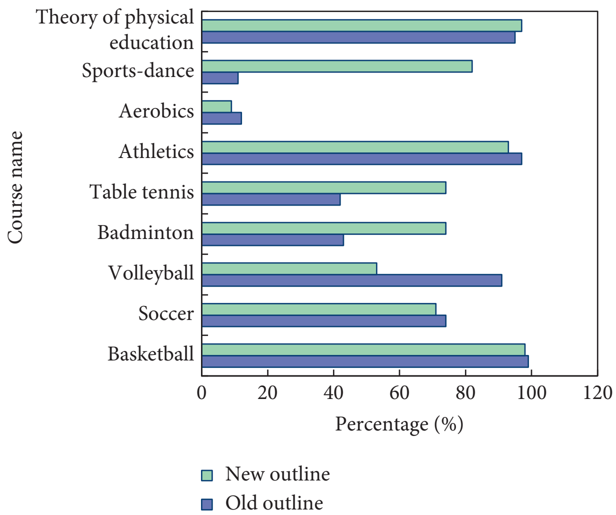

FIGURE 4: Questionnaire statistical results.

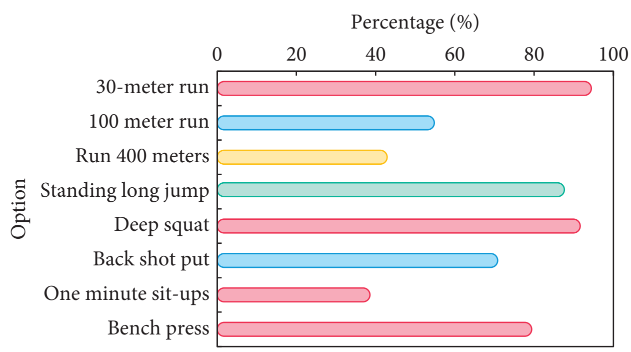

FIGURE 5: Test index selected questionnaire statistical results.

dimensions increases unchanged every time, the improvement speed of the model performance gradually slows down or even stops improving.

The increase in the hidden state dimension will not only bring greater computational complexity, resulting in higher training overhead, but also make the model structure very complicated, which is prone to overfitting problems when the existing data are insufficient. According to the above analysis, in order to balance the model performance and training cost, this article sets the hidden state dimension of the model to 240 dimensions.

When the learning rate of the optimization algorithm is too high, the model loss will drop rapidly at the beginning, but then it will fluctuate greatly, in which case it will not converge. When the learning rate of the optimization algorithm is small, the loss of the model decreases very slowly, and it will take many iterations to achieve the desired effect.

The comparison model mentioned above and CAPR and LSAPR models proposed in this article are trained and tested on two datasets, respectively. Figure 8 shows the statistics of experimental results of different models on two datasets, all of which are obtained by averaging multiple experiments.

The majority of the indexes of the two models on two real datasets exceed the currently popular POI recommendation model or sequence-aware recommendation model,

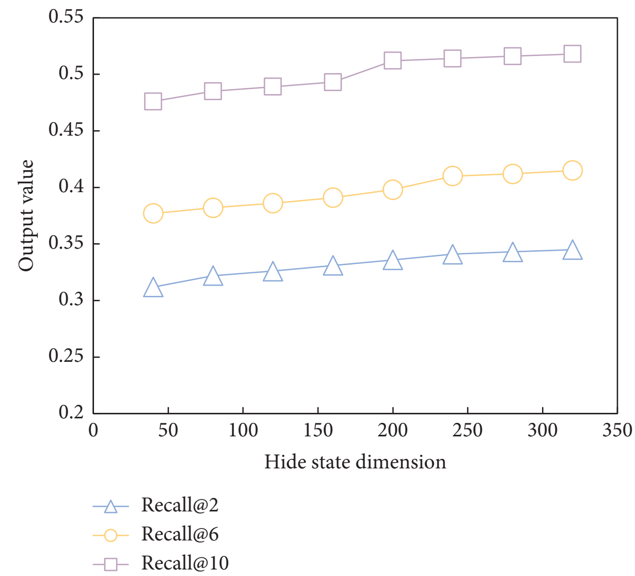

FIGURE 6: Hiding the experimental results of state dimension parameter selection (Recall@K).

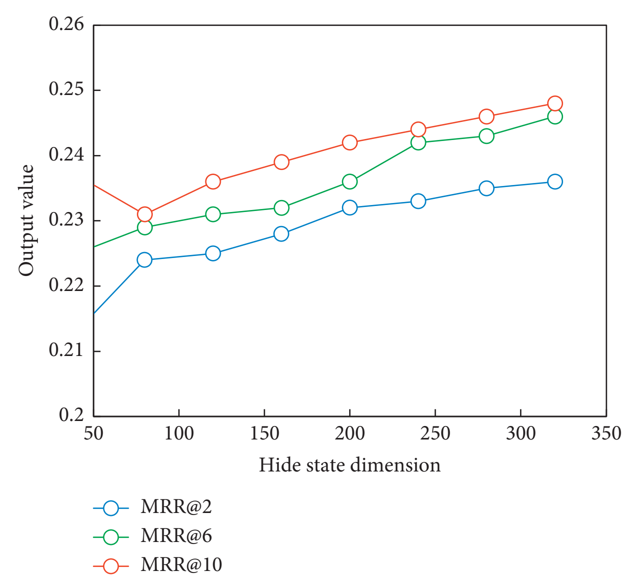

FIGURE 7: Hiding the experimental results of state dimension parameter selection (MRR@K).

according to the analysis of the experimental results in Figure 8. In general, as the length of the recommendation list grows longer, the model's performance on two evaluation indexes improves. Take the model's performance on a 10-item recommendation list as an example for analysis. In general, the CAPR and LSAPR models proposed in this article outperform the comparison model in each of the two datasets' indexes. The experimental results show that the CAPR and LSAPR models can more effectively capture users' long- and short-term preferences, and they can perform well in POI recommendation tasks regardless of whether the users are cold start or personalized recommendations.

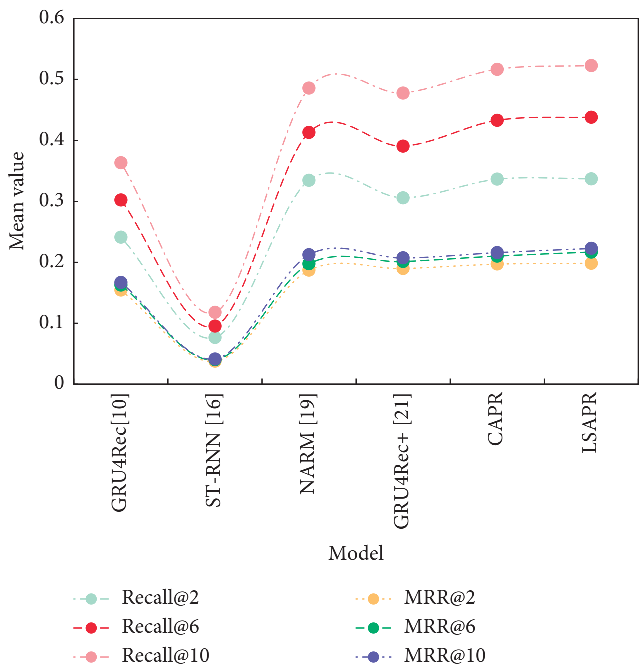

Figure 8: Foursquare comparative experiment results.

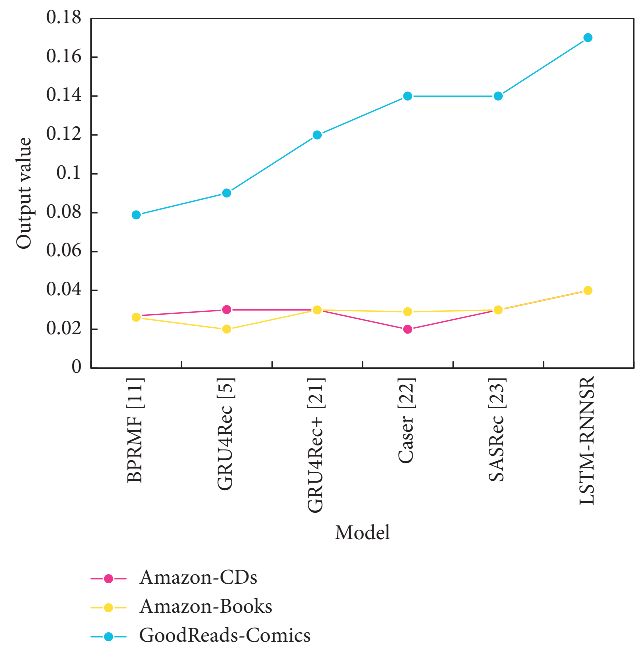

Figure 9: R@8 comparison of different recommendation algorithms.

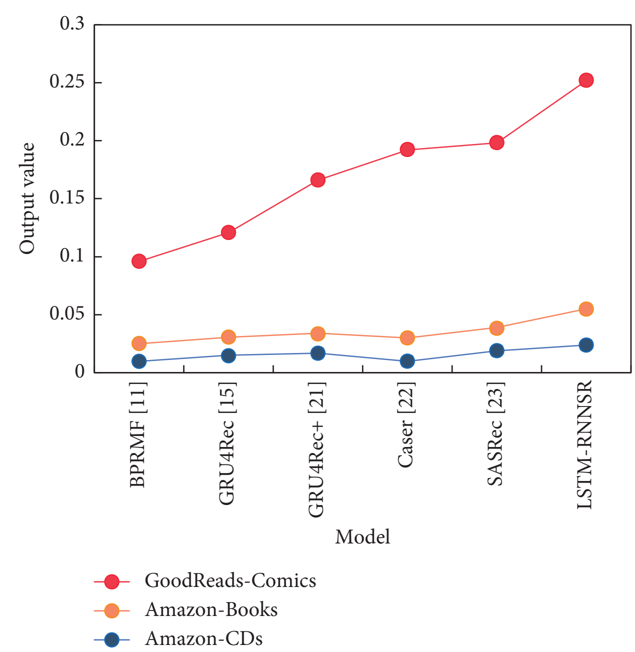

Figure 10: N@8 comparison of different recommendation algorithms.

4.3. Analysis of the Recommendation Model of Preschool PE Curriculum Sequence. In order to verify the recommendation performance of the model proposed in this article, the experiment will compare and analyze the LSTM-RNNSR model in this article with the commonly used recommendation models in three real datasets with different fields and sparsity.

In this article, Recall@k and NDCG@k are used to evaluate the recommendation accuracy of each model. For each user, Recall@k(R@k) represents the percentage of the first k recommended items that appear in the scoring items, and NDCG@k(N@k) is the normalized cumulative loss gain of the first k recommended items, taking into account the position of the correct recommended items.

In this article, six groups of algorithms are tested on Amazon-CDs, Amazon-Books, and GoodReads-Comics datasets, and the difference between the score prediction results of R@8 and N@8 is analyzed. The comparison results of the LSTM-RNNSR model with five comparison algorithms of R@8 and N@8 are given in Figures 9 and 10 respectively.

It can be seen from the table that the recommended performance of the LSTM-RNNSR model on Amazon-CDs, Amazon-Books, and GoodReads-Comics datasets exceeds all comparison methods.

The model LSTM-RNNSR in this article achieves better recommendation performance than SASRec. The main reasons are that SAREC only uses part of the user's historical interactive data, which may lead to the inability to fully learn users' long-term interests, and that SAREC does not explicitly consider the relationship between projects.

Based on BPRMF, this model uses the RNN and AM to capture users' short-term interest preferences and at the same time considers the relationship between users' historical interaction items and prediction items, thus making the model LSTM-RNNSR obtain better recommendation performance.

The effects of different values of item embedded dimension d on the model on Amazon-CDs dataset are shown in Figure 11.

It can be seen from Figure 11 that when the embedded dimension of the project is too small, the model recommendation performance is not good at this time, because the dimension of the project is too small to model the potential characteristics of the project. With the increase in the item embedding dimension d, the model performance gradually improves and becomes stable.

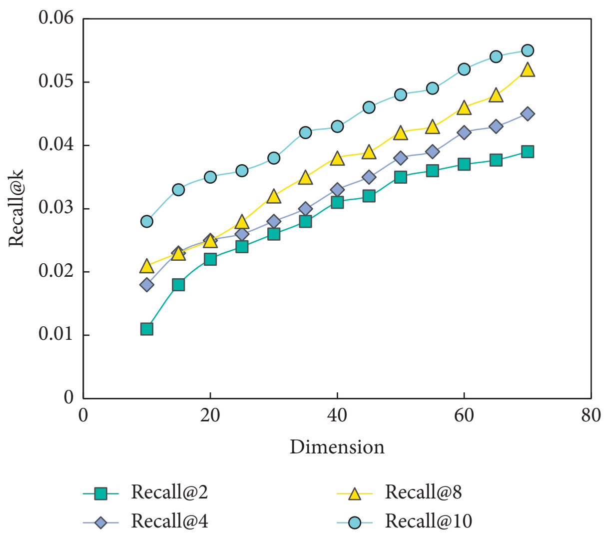

Figure 11: Change in embedded dimension.

5. Conclusion

The teaching status of preschool normal schools can be changed, and the teaching quality and effect can be improved, so that the PE curriculum in preschool normal schools can truly adapt to the future development of students, laying the foundation for cultivating more talents needed by society and improving the quality of preschool education. Based on the improved structure GRU of the RNN and the sequence nature of POI sign-in data, this article designs and implements two POI recommendation models: LSAPR and LSTM-RNNSR. To achieve the goal of personalization, the model uses all of the users' POISSs, as well as the long-term and short-term AM LSAs to more accurately capture the long-term and short-term preferences of users reflected in POISSs. The experimental results of the method proposed in this article on three real datasets with different categories and sparsity show that it outperforms the currently used sequence recommendation methods.

Because of the scarcity of data, the performance of the POI recommendation model may be severely limited. We hope to continue exploring the impact of data sparsity on model performance in the next step and to propose solutions to the problem of data sparsity.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Research on the Intelligent Assignment Model of Urban Traffic Planning Based on Optimal Path Optimization Algorithm

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Congestion and complexity in the field of highway transportation have risen steadily in recent years, particularly because the growth rate of vehicles has far outpaced the growth rate of roads and other transportation facilities. To ensure smooth traffic, reduce traffic congestion, improve road safety, and reduce the negative impact of air pollution on the environment, an increasing number of traffic management departments are turning to new scientifically developed technology. The urban road traffic is simulated by nodes and sidelines in this study, which is combined with graph theory, and the information of real-time changes of road traffic is added to display and calculate the relevant data and parameters in the road. On this foundation, the dynamic path optimization algorithm model is discussed in the context of high informationization. Although the improved algorithm's optimal path may not be the conventional shortest path, its actual travel time is the shortest, which is more in line with users' actual travel needs to a large extent.

1. Introduction

With the rapid development of global economy, the demand for transportation is becoming more and more urgent. However, the possibility of building and expanding roads in big cities is becoming smaller and smaller, and it is impossible to meet the traffic demand only by relying on the construction of infrastructure. Urban traffic congestion has become increasingly global [1]. In recent years, the congestion and complexity in the field of highway transportation are increasing day by day, especially the growth rate of vehicles has far exceeded that of roads and other transportation facilities [2]. More and more traffic management departments rely on today's scientific development of new technologies to ensure smooth traffic, reduce traffic congestion, improve road safety, and reduce the adverse impact of air pollution on the ecological environment [3]. In many cities, the road planning time is earlier, which cannot meet the requirements of modern traffic, resulting in some roads being very crowded. If there is a traffic accident on the main road or road renovation, it will cause long-term congestion and form a certain traffic vicious circle [4]. The intelligent transportation system (ITS) is to make full use of modern communication, positioning, sensors, and other information-related technologies [5] to reduce traffic congestion, improve road throughput, improve traffic safety conditions, and quickly realize the collection and transmission of traffic information, so as to achieve the purpose of reasonably allocating traffic resources and improving ground traffic conditions [6, 7]. Path optimization is the most basic and key part of the dynamic path guidance system. Its main function is to realize the path planning function for users before and during travel, guide vehicles to reach the destination along the optimal route, and realize real-time vehicle guidance based on urban road network information and real-time road traffic condition information [8, 9].

With the rapid development of information technology [10, 11], the development of urban motorization has been continuously promoted. The traffic development of large and medium-sized cities in the world gradually presents problems in road congestion, traffic congestion, and environmental pollution [12]. The resulting traffic accidents and environmental pollution not only inhibit the sustainable development of urban economy to a great extent but also affect the quality of life of urban residents [13]. Traffic jam has seriously affected the operation effect of the urban traffic system, affected the development speed of the city, and caused a great waste of social resources. Even the most advanced traffic system designed and deployed ten years ago cannot adapt to the current reality [14]. After entering the 21st century, due to the influence of geographical environment and historical factors, the available land area of the city continues to shrink, but the number of vehicles continues to surge, so it is impossible to increase the number of roads in the city indefinitely [15]. Traffic management departments increasingly rely on today's scientific development of new technologies to ensure smooth traffic, improve road safety, and reduce the adverse impact of traffic congestion and air pollution on the ecological environment [16]. Combined with graph theory, this study simulates urban road traffic as nodes and sidelines, adds the real-time change information of road traffic, and displays and calculates the relevant data and parameters in the road. To delete the network factors irrelevant to path selection, so as to save the storage space of road network simulation expression, establish the association of storage node elements and line elements, respectively [17].

As a complex system engineering, urban road traffic intelligent control mainly involves disciplines including automation control, engineering technology engineering, system engineering, and optimal dispatching [18]. Because it has many factors such as randomness, complexity, and uncertainty, people cannot establish an accurate mathematical model, so they must rely on intelligent methods [19]. In the transportation system, urban transportation is a very important part. The intelligent development of urban transportation is an important component of the whole intelligent transportation system and the primary task. At the same time, the intelligent development of urban transportation is also a hot spot in the field of traffic intelligent control [20]. The path optimization algorithm studied in this study is an essential and important part of the intelligent transportation system. Its role is to provide path guidance to travelers, and the provided path is the optimal path based on real-time traffic information. In this way, it can reduce the residence time of vehicles on the road, so as to avoid traffic congestion, congestion, and improve urban traffic.

The remainder of the study is laid out as follows. In Section 2, background study and literature review are elaborated. The methodology is discussed in Section 3, followed by experimental setup and results in Section 4. Finally, Section 5 concludes the study.

2. Related Works

The intelligent transportation system can effectively use existing transportation facilities or transform existing facilities and comprehensively use various modern technologies to integrate people, vehicles, roads, and related environments into a system, so that it can play an intelligent role, which can effectively alleviate traffic congestion, ensure smooth traffic, improve road capacity, and reduce the incidence of traffic accidents and a large amount of energy consumption [21, 22]. The urban road network model in the study by Yang and Daoyuan [23] was created using mathematical dynamic programming, which greatly simplified the calculation of the optimal path. Pan and Ma [24] proposed that historical data be added to optimal route selection based on predecessors and that historical data and current road traffic conditions be used to consider all problems in road transportation. Adjustments must be made when traffic conditions change dramatically in order to achieve the best route selection and calculation. However, due to the difficulty in obtaining historical data, this idea is limited and cannot be implemented in practice. In the study by Fulu et al. [25], the Dijkstra algorithm is proposed to realize the optimal route selection in an urban intelligent transportation system, based on the problem of urban traffic. However, selecting and setting parameters in this algorithm is extremely difficult, and traffic lights at road intersections are not taken into account. The use of closed-loop adaptive methods to solve the optimal path selection problem based on urban traffic system problems has been proposed in the study by Sanchez and Herrera [26], so that road traffic conditions can be accurately evaluated according to real-time road conditions, and the optimization calculation function can be used to calculate the optimal path. Calculate the best route. This method performs well in real-time. Because the objective function and linear programming are used in the calculation of the optimal path, the selection of the optimal path cannot achieve real-time effects when the weight of the linear programming changes, affecting the system's accuracy. A sequential algorithm for finding the average shortest path was proposed in the study by Xia [27]. This algorithm can reduce the computational complexity of optimal path selection while increasing its efficiency.

From the traveler's point of view, on the one hand, urban traffic construction gives them more choices in the choice of travel routes. On the other hand, better traffic conditions also reduce the incidence of urban traffic accidents, which not only improves the lives of residents but also improves the civilization of cities. On the basis of previous studies, this study first discusses the algorithm of static optimal path and its complexity, analyzes the traffic confidence and entropy, explains the complexity of traffic information and its complexity through the concept of entropy, and gives the influence of traffic information on traffic behavior. On this basis, it discusses the dynamic path optimization algorithm model under the condition of high informationization.

3. Route Selection Model Based on Real-Time Traffic Information

3.1. Road Network Model and Data Storage Structure. With the rapid growth of urbanization, urban traffic efficiency is becoming increasingly important, and path planning is becoming increasingly important in daily life. Path planning is the process of finding the best path through traffic by artificially designing the system, so that the destination can be reached in the shortest time or by driving the shortest distance. Because the starting point and destination of our travel are both from two nodes in this network and the optimal path can be selected through the search algorithm [28], we should first form a relatively complete network based on the conditions of urban roads, so that we can search for the optimal path in this network. Create a road network model that corresponds to the real-world road network. A road network model can be constructed as follows:

$$\begin{cases} G = (V, E, W), \\ V = \{v_i | i = 1, 2, \ldots, n-1\}, \\ E = \{\langle v_i, v_j \rangle | v_i, v_j \in V\}, \\ W = \{w_{ij} | \langle v_i, v_j \rangle \in E\}. \end{cases} \tag{1}$$

Among them, V represents the set of vertices, E represents the set of edges (sections), and sections $\langle v_i, v_j \rangle$ and $\langle v_j, v_i \rangle$ are the two different sections. W represents the weight set of the road section $\langle v_i, v_j \rangle$, and its attribute value can be selected according to different optimization goals. For the actual urban road network, the traffic information in two directions of the same road section is generally different, so the directed graph is used to express the actual road network. Directed graph increases the storage capacity of the road network, but it can express the real information of outlet network more comprehensively.

The unit for traffic volume is vehicles/h, and it refers to the number of vehicles passing by per unit time on a given road section. There are significant differences in traffic volume at different road sections or intersections due to differences in population density in different parts of cities. The ratio of the time spent by a car passing through a fixed road section to the total time is known as the time occupancy rate:

$$\theta_{ij}(t) = \frac{1}{T} \sum_{k-1}^{N} t_k, \tag{2}$$

where $\theta_{ij}(t)$ is the time required to travel on the road composed of node i and node j in the period t. T is the travel time interval, N is the total number of vehicles passing the road segment in the time period T, and t_k is the time for the vehicles to pass the test point.

There are many ways to calculate the travel time of the road section in path planning. Generally, the relationship between the three quantities of road traffic flow Q, speed V, and density K is used to calculate the average speed. $V = Q/K$, pass. The average speed can be calculated as the travel time $T = L/V$. In the model, the relationship between the time t and the traffic occupancy rate $\theta_{ij}(t)$ on the research section and the average traffic density $K_{ij}(t)$ of vehicle operation can be measured as

$$K_{ij}(t) = \frac{\theta_{ij}(t)}{L_e}. \tag{3}$$

In the formula, L_e is the length of the test vehicle, so the number of vehicles passing in this time, $S_{ij}(t)$, can be calculated as

$$S_{ij}(t) = L_{ij} \cdot K_{ij}(t), \tag{4}$$

where L_{ij} is the length of the road section connected by node i and node j.

In the route planning, the BPR function can be used to calculate the road travel time of the vehicle:

$$w_{ij}(t) = t_0 \cdot \left[1 + \alpha \left(\frac{Q_{ij}(t)}{C_{ij}}\right)^{\beta}\right], \tag{5}$$

where t_0 is the zero-flow impedance, that is, when the traffic on the road section is zero, it is the time required for the vehicle to travel, $Q_{ij}(t)$ is the traffic volume of the road section connected by node i and node j, and C_{ij} is the number of vehicles passing through the intersection in a unit time. C_{ij} can be regarded as a fixed value when traffic congestion occurs at an intersection due to control lights, but the actual traffic flow $Q_{ij}(t)$ is a dynamically changing amount, that is, C_{ij} has nothing to do with $Q_{ij}(t)$. α and β are the retarding functions. In the traffic flow allocation procedure, the values of α and β parameters are $\alpha = 0.15$ and $\beta = 4$, respectively.

The delay time of the road section can be measured by the detector in the system. At the same time, the occupancy rate $\theta_{ij}(t)$ and the traffic flow $Q_{ij}(t)$ of the road section can be measured, and the traffic density $S_{ij}(t)$ can be calculated according to the occupancy rate $\theta_{ij}(t)$. The length of the road segment to be solved is constant, so the number of vehicles EE can be calculated. Finally, $S_{ij}(t)$ and $Q_{ij}(t)$ are combined to solve the delay time $d_{ij}(t)$. Then, compare the delay time $d_{ij}(t)$ with all the green light times of the intersection to calculate the waiting time D_{ij}, so that the delay time of the road section can be calculated at the end:

$$d_{ij}(t) = \frac{S_{ij}(t)}{Q_{ij}(t)} = \frac{\theta_{ij}(t) \cdot L_{ij}}{Q_{ij}(t) \cdot L_e}, \tag{6}$$

where $Q_{ij}(t)$ is the traffic flow of the road section connected by node i and node j, and $Q_{ij}(t)$ and $\theta_{ij}(t)$ can be measured by the detector in the system. The delay time of the road section between different nodes i and j can be calculated by the following formula:

$$\begin{aligned} M &= \mathrm{int}\left[\frac{d_{ij}(t)}{t_u}\right], \\ C_{ij} &= \frac{t_u}{\lambda}, \end{aligned} \tag{7}$$

where C_{ij} is the entire signal period, λ is the green signal ratio, and $d_{ij} = M \cdot C_{ij}$.

Many factors influence actual traffic efficiency, such as traffic flow and road conditions, which directly limit vehicle traffic efficiency. As a result, these factors should be taken into account in the best route selection model, with traffic density and flow playing a key role. Because these two factors are random, unlike the length of a road section, they are fixed for a long time, and they can be factored into the optimal path selection to improve the system's accuracy.

3.2. Dynamic Path Optimization Algorithm. In the process analysis, first, the system administrator creates the station information database and inputs the number, name, longitude and latitude of the traffic station, and the distance between stations in the database. The system administrator is mainly responsible for maintaining the database [29]. After the database is generated, the relevant users can query the optimal path between sites in the query interface, and the users input the name of the starting site and the name of the target site [30]. The system calls the optimized optimal path algorithm to get the optimal path and displays the optimal path result on the display interface. Figure 1 shows the system flowchart.

Express the dynamic road network as $G = (V, E, W)$, where $V = \{V_1, V_2, \ldots, V_n\}$ is a finite node set, which corresponds to the road nodes of the road network. $E = \{V_i, V_j | V_i, V_j \in V\}$, corresponding to the actual road section between road nodes. $W = \{w_{ij}(t), d_{ij}(t) + D_{ij}\}$. Among them, $E = \{V_i, V_j \in V\}$, which means the time it takes for the vehicle to pass through section (V_i, V_j) at any moment.

$w_{ij}(t)$ is the travel time of the road section connected by node i and node j, and the delay time $d_{ij}(t)$ is the road section between nodes i and j, where D_{ij} is the signal waiting time between nodes, and t_u is the transit time at the intersection. $t_u = 30\text{s}$ when $u = 1$. $t_u = 60\text{s}$ when $u = 2$. $t_u = 90\text{s}$ when $u = 3$.

The objective function of the model is

$$\min T = \sum_{i=1}^{N} \sum_{j=1}^{N} x_{ij} \cdot \left\{ \delta w_{ij}(t) + (1 - \delta)\left[d_{ij}(t) + D_{ij} \right] \right\}, \tag{8}$$

$w_{ij}(t) > 0$, $d_{ij}(t) > 0$.

Decision variables are

$$\begin{cases} 1, & 0 < d_{ij}(t) \leq n \cdot t_u \\ 0, & d_{ij}(t) > n \cdot t_u, \end{cases} \tag{9}$$

$$\delta = \begin{cases} 1, & 0 < d_{ij}(t) \leq n \cdot t_u, \\ 0, & t_u < d_{ij}(t) > n \cdot t_u. \end{cases} \tag{10}$$

The formula (9) represents the duration of n green lights, and the size of n is determined by the driver. According to these relations, the time spent on different road sections can be well calculated, and the route is dynamically planned due to the change of the number of signal lights and the change of traffic flow, so as to select an optimal driving route [31].

Aiming at the problem of dynamic path selection, the specific execution steps are as follows. Step 1: initialization, setting the initial node and the destination node. Determine the time occupancy rate, the update time interval of traffic flow, and the size of n. Step 2: find the node adjacent to the starting point, record the node, and calculate the travel time $T_{ij}(t)$ of the road section connected to the node. Step 3: compare $T_{ij}(t)$, if $T_{ij}(t) < t_u$, the road section is relatively smooth, and $T_{ij}(t) = w_{ij}(t)$. If $t_u < T_{ij}(t) \leq nt_u$, then $T_{ij}(t) = d_{ij}(t) + D_{ij}$. If $T_{ij}(t) > nt_u$, the road section is relatively congested, discard the node, and return to Step 2. Step 4: when the next node selected is the destination node, the selection of a set of feasible paths is completed. Step 5: compare multiple groups of feasible paths and take the minimum value.

4. Result Analysis and Discussion

After entering the system, the system administrator first creates the database. Mark the distance values of traffic stations and traffic sections in the database and mainly set the distance values of traffic sections in a straight line way. After the database is created, the user can query the optimal path between traffic stations, input the initial station and the target station, calculate the optimal path according to the optimal path algorithm, and display the optimal path result [27].

During the training phase of the model, it will be tested on the verification set regularly. After continuous analysis and comparison, we finally chose 60 training times as the best training times under the condition that the batch size is 30. Figure 2 shows the trend of accuracy on the verification set along with the training process. Therefore, we can know that increasing the training times within a certain range can improve the performance of the model. On the contrary, too many training times will lead to overfitting, and the performance of the model will decrease.

It can be seen that the accuracy of the verification set of the algorithm is increasing with the convergence of the model, which verifies the correctness of the convergence of the network and the effectiveness of the network for feature extraction.

Adjust the initial model horizontally and vertically. Figure 3 shows the accuracy curve of the model, and Figure 4 shows the loss function curve; with the increase of training times, the accuracy of the network is increasing, and the loss function value is decreasing gradually, and the network basically converges after training 73 times.

During training, the loss function reflected by verification is gradually increasing rather than decreasing, which indicates that the algorithm training has entered the trap of local optimization. Figure 5 shows the relationship between iteration times and normal training and overfitting training.

Combined with the test results of test materials, the correlation between subjective evaluation results and objective evaluation results is 92.08%.

Figures 6 and 7 show the fitting diagrams of subjective evaluation results and objective evaluation results of training samples and test samples, respectively. Combined with the test results of test materials, the correlation between subjective evaluation results and objective evaluation results is 92.07%.

The iterative training is stopped when the training set's fitting degree reaches 98.55%. The test set has a fitting degree of 92.17%, indicating that the model's quality evaluation result is similar to the subjective quality score. When there is not much traffic, the travel time can be very short. When a vehicle approaches a particular road section, for example, it comes to a complete stop due to traffic congestion. The travel time is even longer than the traffic volume. As a result, in

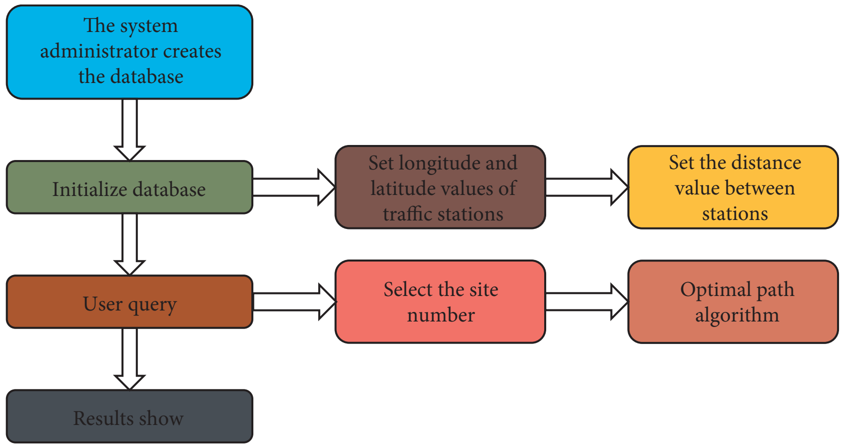

Figure 1: System flowchart.

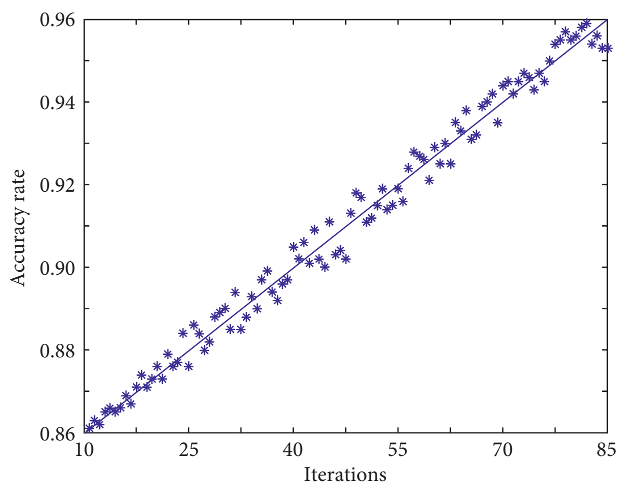

Figure 2: The accuracy trend of the path planning algorithm verification set.

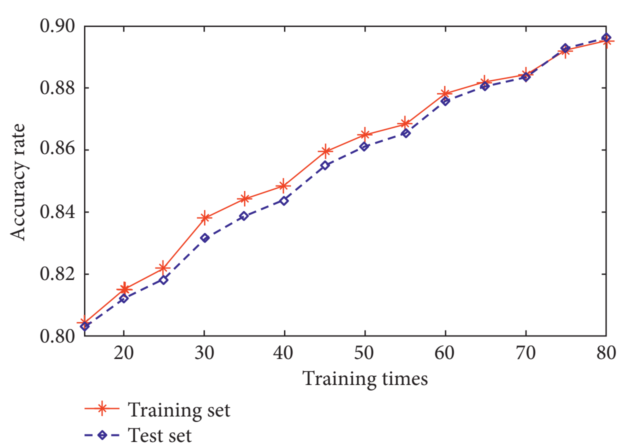

Figure 3: Accuracy curve.

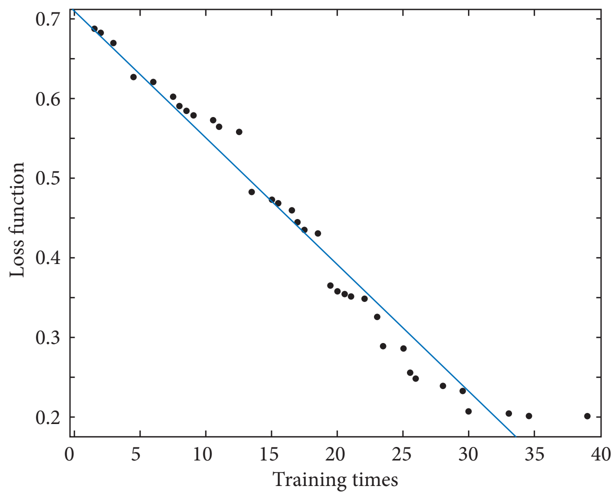

Figure 4: Loss function curve.

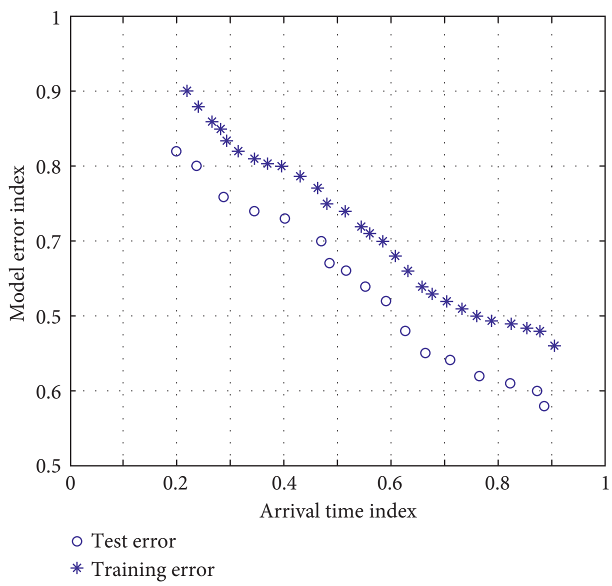

Figure 5: The relationship between the number of iterations and normal training and overfitting training.

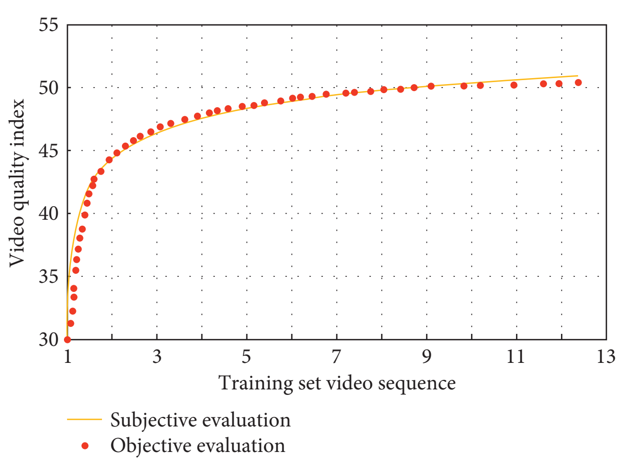

Figure 6: Subjective and objective evaluation values of the experimental training set.

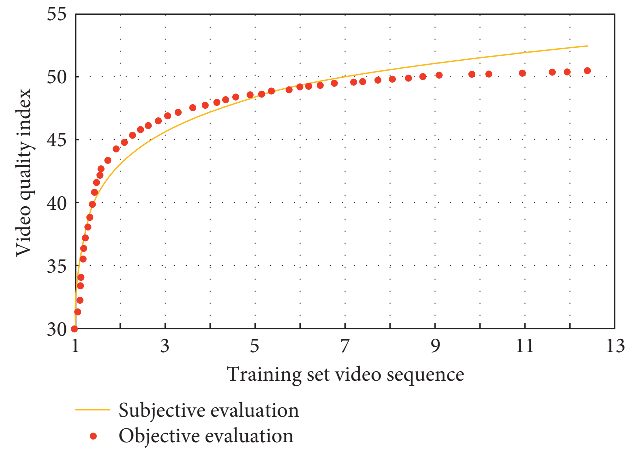

Figure 7: Subjective and objective evaluation values of the experimental test set.

order to effectively improve traffic efficiency, we should collect real-time traffic conditions on the road when planning routes.

5. Conclusions

A key component of an intelligent traffic system is the intelligent traffic management and control system. In order to improve and perfect the intelligent traffic management scheme, the urban intelligent traffic management and control system combines various signal monitoring methods to obtain real-time traffic information and constructs a scientific and reasonable intelligent traffic management framework. The optimal route planning algorithm is the core technology of the route guidance system in ITS, so it is of great practical significance to study it. The intelligent transportation system (ITS) is recognized as the best way to solve the three major problems in the field of international transportation. The intelligent traffic management and control system combines information transmission, allowing relevant management personnel and actual users of the intelligent traffic management and control system to obtain the traffic management scheme and real-time traffic road information in a timely and effective manner, maximizing the efficiency of intelligent traffic management. The main feature of the dynamic path selection problem is that the path selection conditions change over time. Because the majority of the traffic parameters used in the analysis are randomly changed, it is more appropriate to use a dynamic model when analyzing urban road congestion. These influencing factors should be taken into account when designing the road congestion analysis model to improve the accuracy of the analysis results.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Reflections on the Innovation of University Scientific Research Management in the Era of Big Data

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In China, universities are important centers for SR (scientific research) and innovation, and the quality of SR management has a significant impact on university innovation. The informatization of SR management is a critical component of university development in the big data environment. As a result, it is crucial to figure out how to improve SR management. As a result, this paper builds a four-tier B/W/D/C (Browser/Web/Database/Client) university SR management innovation information system based on big data technology and thoroughly examines the system's hardware and software configuration. The SVM-WNB (Support Vector Machine-Weighted NB) classification algorithm is proposed, and the improved algorithm runs in parallel on the Hadoop cloud computing platform, allowing the algorithm to process large amounts of data efficiently. The optimization strategy proposed in this paper can effectively optimize the execution of scientific big data applications according to a large number of simulation experiments and real-world multidata center environment experiments.

1. Introduction

With unprecedented power, information technology is promoting the continuous change of thinking mode and behavioral habits recognized in human daily production and life [1]. Big data technology finds out the relevance of data and extracts valuable information through the correlation analysis of data resources such as SR (scientific research) management system, financial system, personnel system, large-scale scientific literature database, and patent database based on the Internet, which can provide an extensive and scientific theoretical basis for traditional expert qualitative decision management [2, 3]. Because most of this knowledge comes directly from inside the database, it is less restricted and influenced by external resources, has relative independence, and has great guiding significance for SR decisions.

Since university informatization is implemented at the end of the last century, many universities have established and operated various database systems. However, the database systems existing among various departments are not related; thus, a number of information islands are formed in the whole school, which not only lead to a large amount of resources and a serious waste of funds in the school but also bring difficulties to the intensive management of teaching and reasonable study. The SR management system also has its own characteristics [4]. The truly idealized university SR management system is a platform that fully realizes the networking of university SR management, and based on it, forms a data center and management communication platform that can be updated instantly, provides comprehensive and accurate SR information for schools, provides a powerful reference for school leaders to make relevant SR decisions, provides convenient, quick, and thoughtful services for all school teachers to carry out SR activities, and provides great convenience for SR managers [5–8]. With the increasing dependence of SR decision-making system on various data, it is very urgent to actively apply big data technology in university SR management informatization; therefore, more attention should be paid from all aspects, constantly explore and innovate, fully embody the role of big data, and provide assistance for the development of university SR management informatization.

First, A real-time SR business system is established in colleges and universities to improve SR departments' daily business efficiency. Second, an SR decision analysis system is created to ensure that a large amount of SR historical data and current operational data is effectively managed. Then, efficient algorithms are proposed to solve model problems, reduce data communication between data centers for scientific workflow tasks, and thus improve the execution performance of scientific big data applications.

The traditional data mining algorithm and its standalone environment have encountered performance bottlenecks, which can no longer satisfy the processing of massive data. Hadoop is a very simple distributed open-source computing platform, which has excellent advantages such as high efficiency, high reliability, high fault tolerance, and high scalability. Therefore, this paper has improved the NB classification algorithm, and based on the Hadoop cloud platform, it provides a parallel running environment for the data mining classification algorithm.

2. Related Work

Although managers can directly obtain clear information by using tools such as query, information such as relationships and trends hidden in a lot of data cannot be obtained from the data surface [9]. In literatures [10, 11], after analyzing the problems of the application method theory of the traditional management information system in the C/S mode, the idea of improvement is put forward. Literature [12] holds that the supervision of university research funds requires that each project team should have at least two supervisors. However, due to the great correlation between supervisors and research project personnel, supervision is difficult to achieve the expected effect. Literature [13] holds that there are some problems such as low utilization rate of fixed assets and insufficient protection of intangible assets.

Literature [14] holds that because there is no scientific budget accounting system at the national level, researchers and financial personnel have no calculation basis, so they can only calculate by experience, which leads to the incomplete and untrue content of budget preparation and cannot well reflect the research cost of the whole process of SR. Literatures [15, 16] hold that there are two problems in the performance of university SR projects: first, the lack of standards for performance evaluation of SR projects makes the overall performance evaluation unable to be effectively reflected; second, the lack of professionalism in SR content in the performance appraisal group leads to the lack of persuasiveness in performance appraisal results. Literature [17] holds that the person in charge of SR should establish the consciousness of budget management and attach importance to the role of budget in the management of SR funds. Literature [18] holds that internal control should be taken as the starting point to improve the management level of SR projects and the use efficiency of funds. Literature [19] holds that strengthening the performance evaluation of SR funds should start from two aspects: the use benefit evaluation of SR funds and the benefit of SR work. Paying attention not only audits compliance, legality, rationality, and authenticity of the income and expenditure of SR projects but also comprehensively evaluates their economic benefits, technical benefits, and social benefits. In the aspect of performance evaluation of research funding, literature [20] holds that the evaluation method combining individuals and teams can be adopted, which should pay attention to both the cultivation of individual abilities and the collective performance appraisal so as to realize the circular development of individual interests and teams.

With the help of data mining technology, the university SR management innovation information system studied in this paper has actually solved the problems of multilevel characteristics and weight distribution of indicators, uncertainty of evaluation results, and deep mining [21] of evaluation data in the process of establishing the evaluation system, which makes the evaluation system more scientific, reasonable, and reliable.

3. Research Method

Construction objectives and system functions of the university SR management information system are put forward, and the overall design scheme of the system is designed. The NB classification algorithms are analyzed, and based on their advantages and disadvantages, improvements are made, and the SVM-WNB classification algorithm, a combination algorithm of SVM and WNB classification algorithm, is proposed. The related models and algorithms of data layout and task scheduling are researched, and a scientific big data application workflow management system is implemented.

3.1. Overall System Design Scheme. It combines B/S with C/S to form B/W/D/C/S (browser/web/database/client/server) architecture [22], and users can access the database locally and remotely at the same time.

A real-time business subsystem of SR adopts the B/S mode. Users of other departments and Internet users access the database server of the network center to obtain the news released to the outside world, and the two servers make a differential copy at a certain time period to achieve the consistency of data.

According to the setting scheme of B/W/D/C architecture, the development platform of the system can adopt the following scheme, as shown in Figure 1.

Windows Server 2003 seamlessly integrates network management with the fundamental operating system, making the network simple to use and manage. Its internal architecture is entirely 32 bit, and there are multiple threads running at the same time, allowing it to support more powerful applications. At the same time, the system's stability is ensured by providing separate memory space for the operating system and application programs to avoid data conflict.

The system's database is SQL Server 2000, a relational database product with many features such as data query

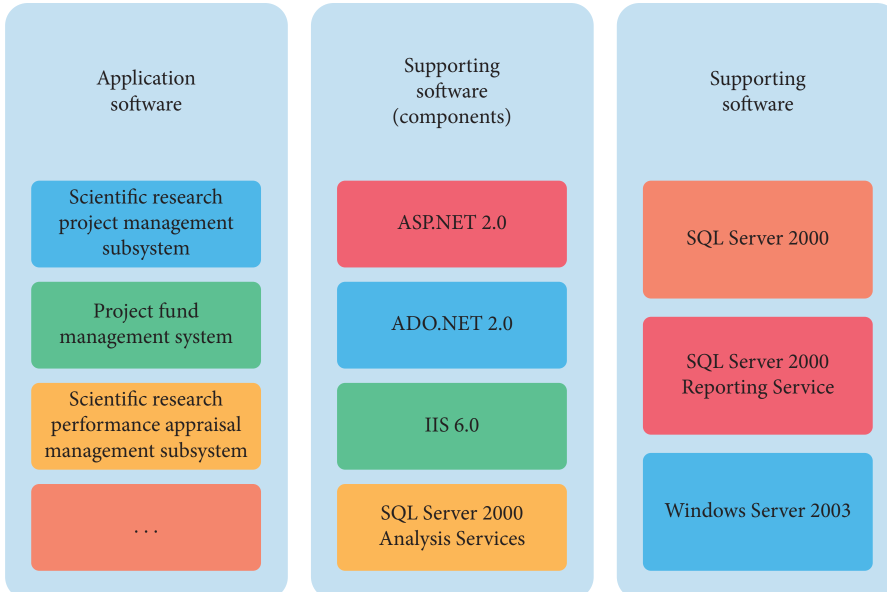

Figure 1: System development platform configuration.

diversity (SQL, XML), data integrity, high data access efficiency, concurrency control, transaction processing, data disaster protection, data diversification, security, and ease of use.

Our entire C/S mode SR decision analysis subsystem running platform is based on Visual Basic 6.0, which provides comprehensive component-based programming support, allows us to quickly build professional application systems for customers, reduces development and coding workload, and allows developers to focus more on communicating with users' needs.

3.2. Big Data Classification Algorithm. The basic idea of the NB (Naive Bayes) classification algorithm is simple and easy to understand, mainly assuming that the attributes between classes are independent of each other and they do not influence each other. Assuming that there are n classes $C_1, C_2, \ldots, C_n$, a sample X to be classified is given, then if and only if

$$P(C_i|X) > P(C_j|X), \quad 1 \le j \le n,\ j \ne i. \tag{1}$$

At this time, the sample X belongs to C_i; that is, the NB classification algorithm assigns the sample X to be classified to the class with the highest posterior probability.

Because the NB classification algorithm assumes that the attributes of classes are independent of each other, the classifier model of the algorithm is very simple, as shown in Figure 2, which is the structure diagram of the NB classifier model.

The NB classifier model structure is a tree-like Bayesian network, which includes a root node representing class variables and some leaf nodes representing attributes, among which attributes are independent of each other.

The NB classification algorithm also has its disadvantages. If the training sample set or the sample set to be classified has a very large scale, the cost of the NB classification algorithm will become very large.

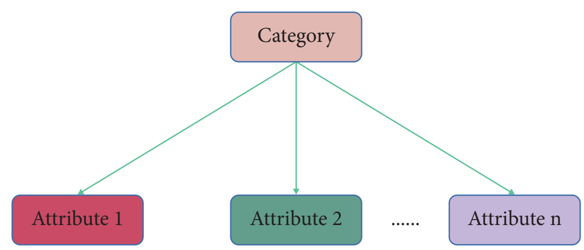

Figure 2: Structure diagram of NB classifier model.

The SVM (Support Vector Machine) algorithm often classifies samples incorrectly near the optimal classification hyperplane. For the NB classification algorithm, theoretically, the NB algorithm has very good efficiency and minimum error rate [23, 24], and the assumption of class condition independence reduces the computational cost of the algorithm. However, in practical application, such a hypothesis is impossible.

Based on the advantages and disadvantages of these two algorithms, the WNB (Weighted NB) classification algorithm can be obtained by improving the NB classification algorithm by weighting. Then, combining the two algorithms is considered to form a new algorithm, which is called the SVM-WNB (Support Vector Machine-Weighted NB) classification algorithm.

Assuming that w_k is the weight coefficient of attribute A_k, the WNB classification algorithm can be expressed by the following formula:

$$\underset{C_i \in C}{\operatorname{argmax}}\ P(C_i)\prod_{k=1}^{n} P(x_k|C_i)^{w_k}. \tag{2}$$

Here, two different methods are selected to calculate the weight coefficient w_k, and the average of w_{k1} and w_{k2} is obtained, respectively, and then, this average is taken as the final value of w_k, and w_k is put into the above formula for calculation. The following is a description of these two ways.

Assuming that the conditional attribute and decision attribute are X, Y, their mathematical expectations are $E(X), E(Y)$, and covariance, respectively:

$$\mathrm{Cov}(X,Y) = E(X,Y) - E(X)E(Y) = E[(X - E(X))(Y - E(Y))]. \tag{3}$$

The correlation coefficient ρ can be expressed as follows:

$$\rho = \frac{\mathrm{Cov}(X,Y)}{\sqrt{D(X)D(Y)}}. \tag{4}$$

The smaller the correlation coefficient ρ, the smaller the influence of condition attribute X on decision attribute Y. On the contrary, the larger the correlation coefficient ρ, the greater the influence of condition attribute X on decision attribute Y. Therefore, the correlation coefficient ρ can be used to weight the attributes, and w_{k1} can be expressed as follows:

$$w_{k1} = |\rho| = \left|\frac{\mathrm{Cov}(X,Y)}{\sqrt{D(X)D(Y)}}\right|. \tag{5}$$

The second method is relatively simple; that is, the weight coefficient is obtained by calculating the correlation probability, assuming that there is an attribute A_k, and a_k is the value of the attribute A_k. The number of attributes whose value is a_k can be expressed as $\mathrm{Num}(A_k = a_k)$. The attribute A_k takes the value of a_k, and the number belonging to class C_i can be expressed as $\mathrm{Num}(A_k = a_k \wedge C_i)$. w_{k2} can be expressed as follows:

$$w_{k2} = \frac{\mathrm{Num}(a_k \wedge C_i)}{\mathrm{Num}(A_k = a_k)}. \tag{6}$$

Two different methods are used to select the weight coefficient, and finally, the average value is taken, which makes the selection of the weight coefficient more reasonable. Different attributes and different weight coefficients effectively improve the accuracy of classification.

3.3. Scientific Workflow Scheduling. Scientific workflow scheduling is built on the foundation of scientific workflow and data center modeling, so the scheduling model must first model scientific workflow and data center and then consider the characteristics of scientific workflow scheduling and model workflow scheduling in a reasonable and accurate manner.

For the application of scientific big data, the DAG (Directed Acyclic Graph) model is usually used to represent the complex execution and data dependency among workflow tasks. In this study, the DAG model of scientific workflow is expressed as follows:

$$G = (V \leftarrow D \cup T, E, \omega, \theta), \tag{7}$$

where V represents the node set of the graph, including the dataset D and the task set T.

As shown in Figure 3, this study assumes that each task has an output dataset that can be used by many subsequent tasks.

At any level of coarsening l, in this paper, the optimized random connection weight matching method is used to aggregate the nodes of graph G_1. The nodes in the graph G_1 are randomly accessed. For each accessed node $v_i \in V^l$, if it has not been aggregated, the node v_j with the largest edge weight among the nodes connected to it and not aggregated is selected for aggregation.

If the edge connected with multiple nodes has the largest weight, the node with the best weight balance after aggregation is selected as follows:

$$f_{v_u} = (\tau(v_u) - \tau(k))^2, \tag{8}$$

where v_u is the vertex after aggregation, $\tau(v_u) = \omega_{cp}(v_u)/\sum_{v\in V}\omega_{cp}(v)/\omega_{st}(v_u)/\sum_{v\in V}\omega_{st}(v), \tau(k) = cp_k/\sum_{k\in K} cp_k/st_k/\sum_{k\in K} st_k$. The smaller the q f_{v_u} value, the better the balance.

In order to make the hybrid GA (genetic algorithm) search only the feasible solution space, the fitness function set by this algorithm is as follows:

$$\mathrm{fit}(I) = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} * \sum_{k=1}^{K} Z_{ijk}. \tag{9}$$

The general idea of the algorithm is based on the concept of revenue, which is the reduction of the total division cost when the nodes are moved between the two divided parts. The benefits can be positive or negative, and the positive benefits indicate that the cost of mobile node division is reduced; it is consistent with the purpose of the study, which is the hope of this study; and negative returns need to be avoided.

$(G_t, G_{t'})$ denotes the two disjoint partitions, namely, $G_t \cap G_{t_l} = \varnothing$. The symbol $\mathrm{gain}(v_i, G_{t'})$ indicates the reduction of the division cost when the node $v_i \in G_{t'}$ moves to $G_{t'}$ gains; $\mathrm{gain}(v_i, G_{t'})$ can be calculated by the following formula:

$$\mathrm{gain}(v_i, G_{t'}) = g(v_i, G_{t'}) = g(v_i, G_t), \tag{10}$$

where $g(v_i, G_t)$ represents the sum of the weights of the edges connected with v_i in the partition G_t.

$v_i \in V_t$ iteration is moved to the appropriate data center according to the descending order of maximum profit until the partition meets the constraints of the corresponding data center.

4. Analysis and Discussion

4.1. Parallel Processing of Algorithm and Experimental Analysis. It is feasible to parallelize the SVM algorithm on the Hadoop cloud computing platform. In the NB classification algorithm, when the dataset or attributes is too large, the cost of storing samples and calculating probability is very huge, and the classification performance will be significantly reduced. However, because the data processed by the NB algorithm are mutually independent [25], and the process of calculating the probability of data is also mutually independent, the data

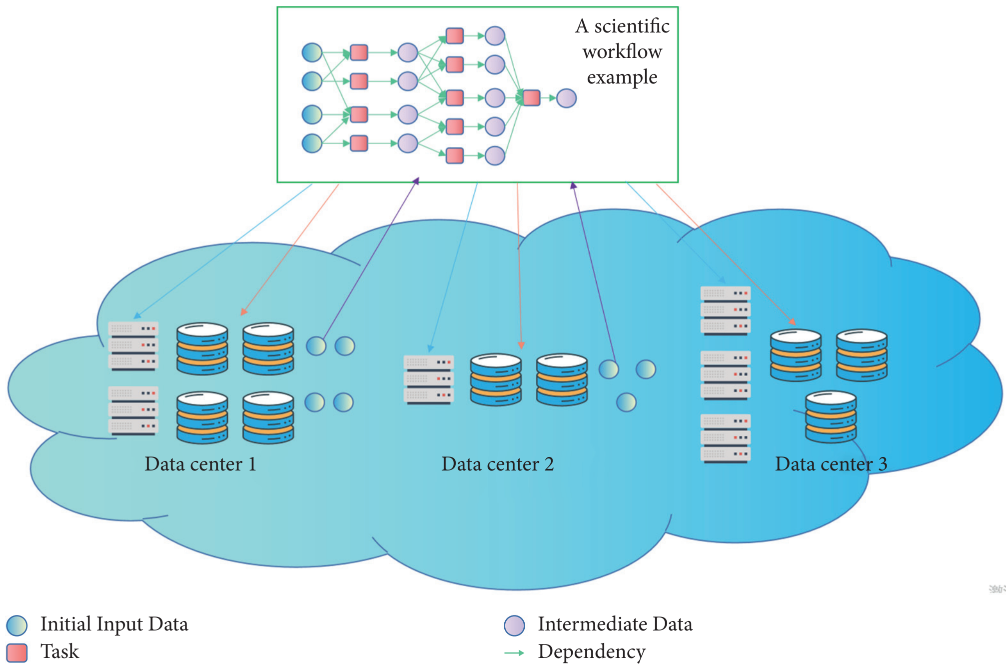

Figure 3: Schematic diagram of scientific workflow scheduling.

processed by the NB algorithm can be easily divided into balanced blocks. Through the above analysis, it is clear that the SVM-WNB classification algorithm is feasible.

In this experiment, the penalty parameter $C = 5$, the decision threshold $\xi = 0.6$, the radial basis kernel function parameter $g = 0.1$, and $K = 5$ in the nearest neighbor algorithm are selected, and mapred.map.tasks to 3 and mapred.reduce.tasks to 4 in Hadoop are set; that is, the number of maps is set to 3 and the number of reduce is set to 4.

For the multiclassification problem of the SVM algorithm, a one-to-one classification method is adopted (69), and $n(n-1)/2$ SVM classifiers are constructed for n categories.

The test sample set will be divided here in order to ensure the comprehensiveness and accuracy of the experimental results, and some samples will be randomly selected as experimental test data, and the final mean value will be taken as the result of many experiments.

The hSVM-WNB classification algorithm, NB algorithm, and SVM-WNB classification algorithm are compared after randomly selecting 10,000, 50,000, 100,000, 250,000, 500,000, 750,000, and 1 million test cases from the test sample set. The accuracy and processing time of these three algorithms are compared in Figures 4 and 5, respectively.

Figure 4 shows that the SVM-WNB classification algorithm is more accurate than the NB algorithm. On the one hand, it improves classification accuracy by optimizing the algorithm by weighting attributes in various ways; on the other hand, it selects and uses the optimized WNB algorithm to process near the classification hyperplane of the SVM algorithm. The hSVM-WNB classification algorithm maintains good accuracy even when the number of test cases is large due to parallel processing.

Figure 5 shows that the SVM-WNB classification algorithm requires two classifiers to be trained, whereas the NB algorithm is very fast, so the NB algorithm is faster than the SVM-WNB classification algorithm in terms of processing time.

4.2. Analysis of the University SR Management System. The workflow used for testing in this experiment was generated by the Pegasus workflow generator. The ratio between the amount of resources provided and the amount of resources required in this group of experiments is 1 : 2.

For each workflow task, the required computing resources are uniformly distributed among (1, 10), and the unit is the number of CPU cores. The size of each data obeys the uniform distribution of (1, 100) in GB.

It can be seen from Figure 6 that among the four candidate algorithms for Montage workflow, the hybrid GA algorithm (hybrid GA) has the best scheduling effect, reducing the data transmission by 40.1% and 30.4% compared with the RRLocality and KCut algorithm. Because the KCut algorithm is designed based on the maximum flow minimum cut theory, all parts of the workflow after division are extremely unbalanced, which shows that some divided parts contain most workflow tasks and data nodes.

However, due to the limitation of computing and storage resources in the data center, it is necessary to adjust the partition that does not meet the constraint conditions, which leads to the deterioration of the results.

From Figure 7, it can be seen that with the increase of data centers, the amount of data transmission across data centers also shows an increasing trend. If the workflow is dispatched to more data centers, more dependent edges will

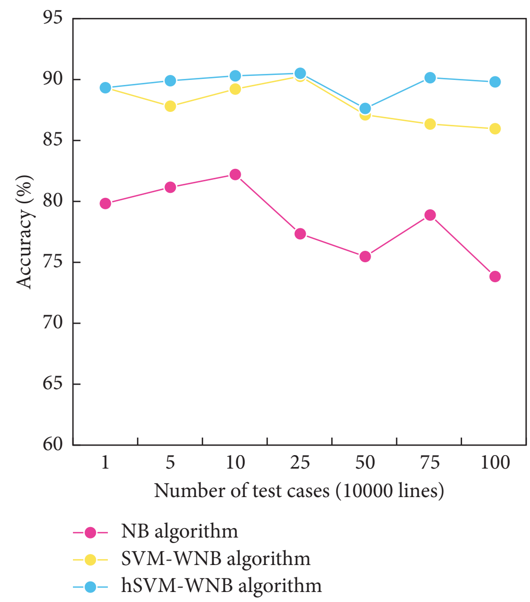

Figure 4: Comparison chart of classification algorithm accuracy.

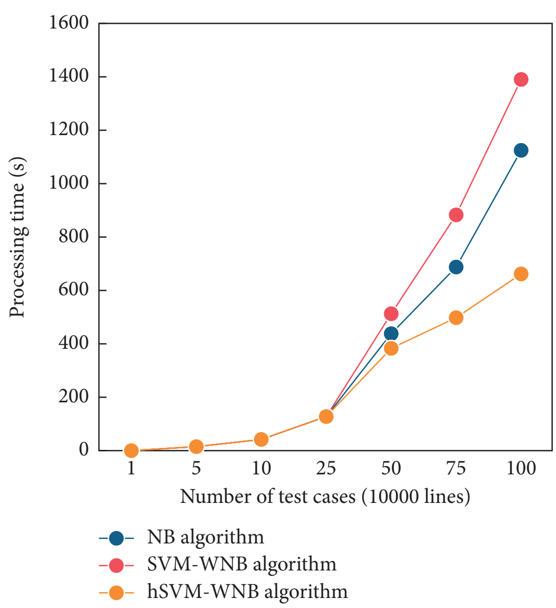

Figure 5: Comparison chart of classification processing time.

be divided, which will lead to the increase of data transmission across data centers.

Figure 8 shows a Montage workflow with 500 tasks that was sent to four different data centers to investigate the impact of changing data center capacity on data transmission across data centers. The ratio between the amount of resources provided by the data center and the amount of resources required in this experiment is set to gradually increase from 1.2 to 1.5, with a 0.05 increment.

As shown in Figure 8, for Montage workflow, the hybrid GA algorithm is the best candidate algorithm. It is not difficult to find that with the increase of data center capacity, the data transmission volume of workflow across data centers shows a downward trend. This is due to the increase

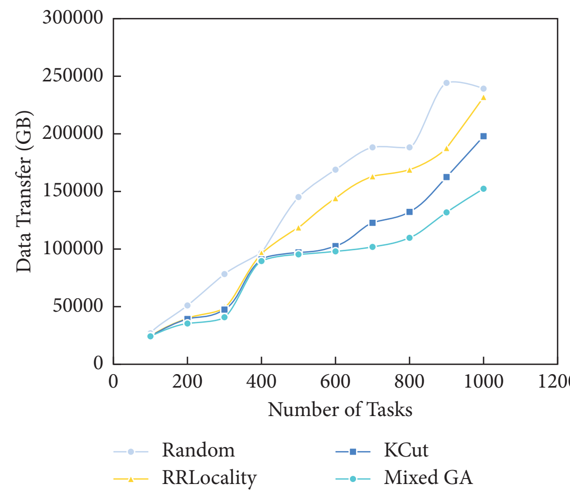

Figure 6: Influence of the number of workflow tasks on data transmission.

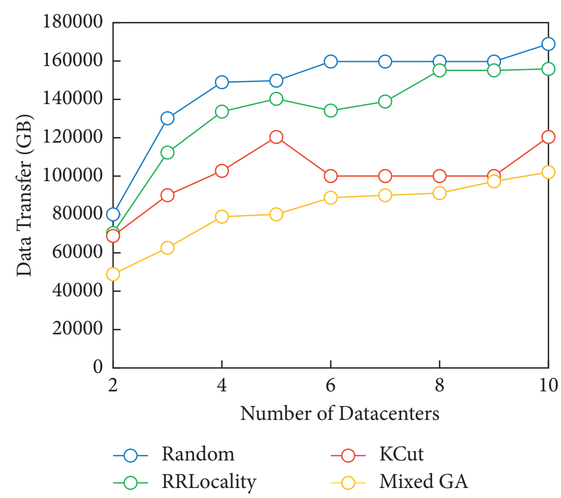

Figure 7: Influence of the number of data centers on data transmission.

of data center capacity, which greatly reduces the tasks or data that are forced to be placed in nonoptimal data centers due to data center capacity limitations, thus reducing the amount of data transmitted across data centers.

This system middleware is based on Globus Toolkit-6.0, which consists primarily of the following components: grid security of multidata centers is handled by GSI and MyProx; data management is handled by 2GridFTP; task management is handled by GRAM5, and grid infrastructure is built by a group of C language common libraries.

After the system middleware has been installed, the workflow management software must be installed on the submission node in order to complete the workflow definition, mapping, and submission for execution. This section of the function is based on the Pegasus system, an open-source workflow management software that implements the data layout and workflow scheduling strategy proposed in this paper. The Pegasus workflow management system includes an implementation interface for defining and

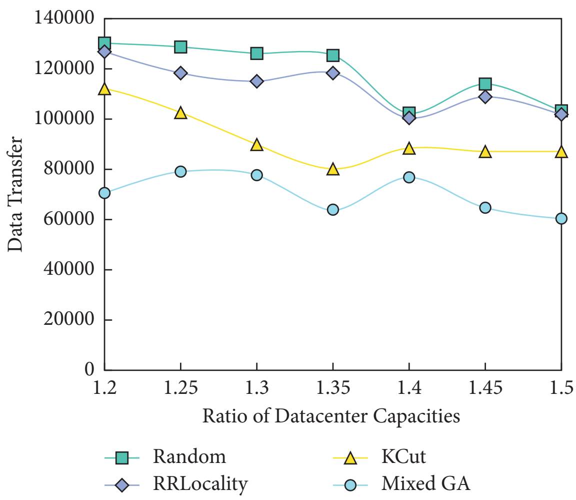

Figure 8: Influence of data center capacity on data transmission.

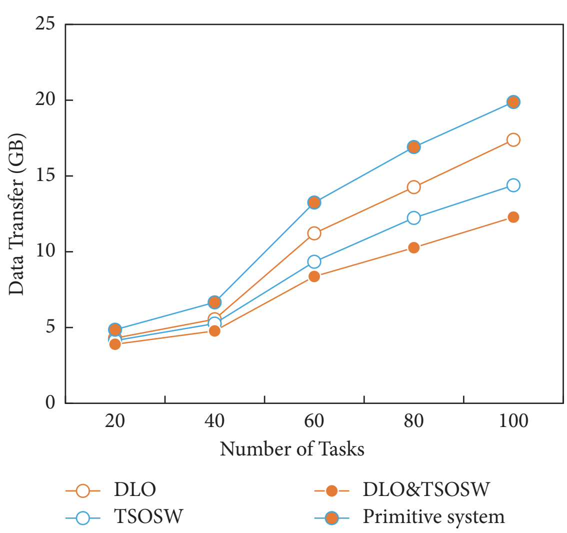

Figure 9: Influence of different policies on data transmission amount of AMS workflow execution.

analyzing workflows, as well as submitting them for execution in a multidata center environment.

In order to test the optimization efficiency of the scientific big data application implementation of the optimization strategy proposed in this article, this paper considers three optimization strategies: DLO (data layout optimization), TSOSW (task scheduling optimization of scientific workflow), and DLO and TSOSW (comprehensive optimization of two strategies), and the original system is compared.

The system execution environment consists of three data centers, namely, the cloud data center of a university, the dawning data center, and the data center built by several servers. The experimental data are AMS scientific data, which are distributed and stored in a multidata center environment. Due to the long running time of a large-scale scientific workflow and the huge data scale required, this

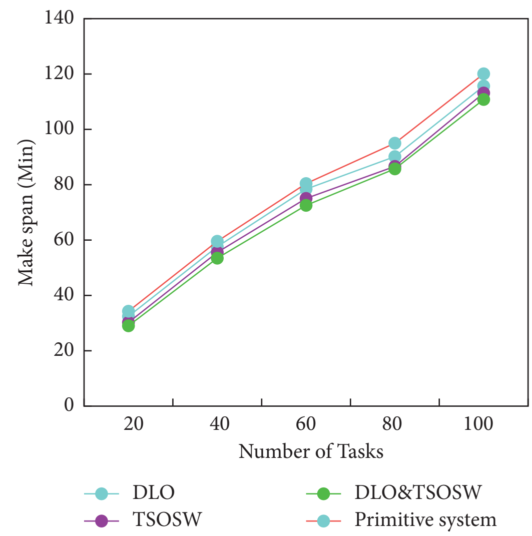

Figure 10: The effect of different policies on AMS workflow execution time.

paper uses small- and medium-scale scientific workflow to perform the test, and the number of workflow tasks ranges from 20 to 100.

Figures 9 and 10 are statistical charts of data transmission volume and corresponding execution time of AMS scientific workflows of different scales across data centers under different strategies.

Compared with the original system, DLO and TSOSW strategy reduces the data transmission by 34.1% on average and the execution time of workflow by 26.2%. Compared with TSOSW, the optimization effect of DLO is slightly worse. The reason may be that the execution position of the task has a greater influence on the data transmission. Only when the task is dispatched to the data center where the input data are located, the data transmission can be better optimized, and the execution efficiency can be improved.

5. Conclusion

SR is a source of national innovation and development, as well as a catalyst for scientific and technological progress and social progress. University SR management is a powerful guarantee for university SR's rapid development. In light of the rapid advancement of educational informatization, university SR management departments should introduce and utilize big data technology to provide an impetus for university SR's healthy and rapid development. This paper builds a comprehensive university SR management innovation information system using data warehouse and big data technology. The SVM-WNB algorithm is proposed, and attributes are weighted and improved. The hSVM-WNB algorithm was then transplanted to the Hadoop cloud computing platform for distributed processing. A series of experiments have shown that the parallelization of the new algorithm is possible, which could be very useful in practice. Using a special hybrid GA algorithm, a novel heuristic method is proposed that can effectively reduce data transmission across data centers during workflow execution.

The front end of the system does not provide good data mining functions for users because the data mining model is not included in the background design and development of the system. One of the next major tasks is to add a data mining function to this system so that it can function as a comprehensive decision support system.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

A Novel Financial Risk Early Warning Strategy Based on Decision Tree Algorithm

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This paper requires a lot of assumptions for financial risk, which cannot use all of the data and is often limited to financial data; and in the past, most early warning models for financial crises did not, so they could not track the fluctuation and change trend of financial indicators. A decision tree algorithm model is used to propose a financial risk early warning method. Enterprises have suffered as a result of the financial crisis, and some have even gone bankrupt. Any financial crisis, on the other hand, has a gradual and deteriorating course. As a result, it is critical to track and monitor the company's financial operations so that early warning signs of a financial crisis can be identified and effective measures taken to mitigate the company's business risk. This paper establishes a financial early warning system to predict financial operations using the decision tree algorithm in big data. Operators can take measures to improve their enterprise's operation and prevent the failure of the embryonic stage of the financial crisis, to avoid greater losses after discovering the bud of the enterprise's financial crisis, and to avoid greater losses after discovering the bud of the enterprise's financial crisis. This prediction can be used by banks and other financial institutions to help them make loan decisions and keep track of their loans. Relevant businesses can use this signal to make credit decisions and effectively manage accounts receivable; CPAs can use this early warning information to determine their audit procedures, assess the enterprise's prospects, and reduce audit risk. As a result, the principle of steady operation should guide modern enterprise management. Prepare emergency plans in advance of a business risk or financial crisis to resolve the financial crisis and reduce the financial risk.

1. Introduction

In the fierce market competition environment, many enterprises fall into financial difficulties or even bankruptcy due to poor management [1]. Enterprise financial risk means that enterprises may encounter some problems in the process of financial work, and the existence of these problems is likely to affect the normal operation and development of enterprises [2]. Enterprise financial risk early warning means that enterprises can alert these financial risks before encountering such problems, so as to help enterprises find the signs of possible risks in the process of financial work in advance [3]. In the process of enterprise financial work, financial risk early warning has always been the content that enterprise management leaders attach great importance to. Once an enterprise has financial risk, it is likely to cause serious losses to the enterprise's economy and seriously lead to the rupture of the enterprise's capital chain, making the enterprise face the risk of bankruptcy [4]. Therefore, it is important to strengthen the early warning of enterprise financial risk [5]. The quality of enterprises is related to the stability and development of the securities market. How to build an effective financial crisis early warning system for various interest groups of enterprises to help enterprises accurately predict financial risks and reduce losses is more important. In the economic field, some scholars have also done some research on financial risk early warning based on decision tree, but the data is simply balanced, and the research on algorithm is not comprehensive enough [6]. However, in the process of enterprise development, there is often a lack of effective risk early warning mechanism and risk control system scheme. Generally, financial risk problems are analyzed through post disposal, qualitative and static. At present, the research on financial risk early warning system is very lacking.

Decision tree algorithm is one of many data mining algorithms. With the rapid development of information technology [7], the related theory and application are becoming more and more mature. The decision tree does not need to assume a priori probability distribution and has good flexibility and robustness; not only discrete and continuous numerical samples, but also "semantic data" can be used. The generated rule set has simple structure, strong interpretability, and high computational efficiency. It can effectively suppress sample noise and attribute deletion. The disadvantages are as follows: the classification rules are complex and it has overfitting phenomenon.

This paper constructs a financial risk [8] early warning model based on the C4.5 algorithm of decision tree [9], uses the key financial indicators generated by the analysis of financial risk analysis system as the attribute set of decision tree, obtains the preliminary financial risk early warning model by analyzing the sample data of financial indicators, and then adds and integrates the representative branches of decision tree model by post-pruning, repeated experiments are carried out to verify the algorithm model, and final financial risk early warning model is obtained [10].

2. Related Work

Financial risk exposure is frequently the final stage of overall risk exposure, in which all potential problems manifest themselves as financial risk. In fact, data mining [11] can be used to retrieve data that can predict potential financial risks at an early stage. Because potential problems usually manifest themselves in nonfinancial or difficult-to-quantify indicators (such as moral hazard and agency cost), there are currently few studies of this type. In addition to financial indicators, the balanced scorecard concept is based on a set of theories [12].

According to consulting and analyzing a large amount of relevant literature on the occurrence, formation, harm, and treatment of financial risk, this paper makes a comprehensive analysis on the problems existing in the early warning management in the current financial risk management, in order to study the financial risk early warning through more scientific and practical research methods, and make the research results improve in practical application. In terms of processing methods, it mainly studies the theory and method system of financial risk early warning by using the algorithm of decision tree and other relevant methods on the basis of financial analysis theory, category unbalanced analysis theory, and early warning decision theory.

At present, there are many views on the definition of financial risk, and there is still no unified standard [13].

The literature holds that financial distress is the obstruction of enterprises in performing their obligations, which is embodied in four forms: insufficient liquidity, insufficient rights and interests, debt arrears, and insufficient funds [14].

According to the literature, companies in financial distress only include companies that have gone bankrupt, become insolvent, or have been liquidated for the benefit of creditors. It is considered that financial risk not only is defined as bankruptcy, but also includes debt default, bank overspending, failure to pay preferred stock dividends, and so on. The literature holds that bankruptcy is only a single event in a series of potential failures of companies with financial crisis tendency [15, 16].

Financial risk exposure is frequently the final stage of overall risk exposure, in which all potential problems manifest themselves as financial risk [17]. In fact, data mining [11] can be used to retrieve data that can predict potential financial risks at an early stage. Because potential problems usually manifest themselves in nonfinancial or difficult-to-quantify indicators (such as moral hazard and agency cost), there are currently few studies of this type. In addition to financial indicators, the balanced scorecard concept is based on a set of theories [12].

The document [18] is unable to pay the creditor's debts when due and is applied for bankruptcy by the creditor. The creditor's application for bankruptcy does not mean that the company is in fact bankrupt. Bankruptcy must be determined by the court's judgment. Before the court declares bankruptcy, the creditor and the debtor may reach a bankruptcy settlement agreement and reach a settlement agreement on the debtor's delay in paying off debts and reducing the amount of debts. After the court determines, the bankruptcy proceedings can be terminated [19].

The book net assets and shareholders' equity of the company are negative [20]. It shows that the company's assets are less than liabilities, and the risk of failure to repay debts is high; at least it is insolvent on the book. However, it does not mean that the company's financial crisis is serious, because many companies have some assets that have not been reasonably evaluated, and the actual value of these assets will greatly exceed the book value [21]. In any case, as long as the shareholders' equity is negative, it is considered that the company's operation is poor and the financial risk is large. The company is unable to perform the interest and principal repayment of the due contract. Once creditors apply to the court for bankruptcy, the company will fall into bankruptcy crisis [22].

In the application process of financial crisis early warning model, there are usually two kinds of errors: misjudging a crisis company as a healthy company and a stable company as a crisis company. The costs of these two errors are generally different. However, in the current domestic research, we usually assume that the cost of these two types of errors is the same, which will obviously affect the practicability of the model. This paper does not generally define a specific sign such as bankruptcy or financial risk, but classifies the financial risk of listed companies in different periods of operation and development into each link of the early warning chain according to the form of the early warning chain and selects the corresponding financial risk form as the early warning target according to the company's financial status and its specific link in the early warning chain [23].

3. Principle of Correlation Algorithm

3.1. Analysis of Financial Crisis Early Warning and Risk Control Based on Decision Tree. Generally speaking, financial risks include capital structure and cash flow risk, accounting and process risk, and accounting and financial reporting risk. The financial crisis studied in this paper only considers the capital structure and cash flow risk (or liquidity risk) [24]. More specifically, we will analyze from the perspective of the project. If the cash flow of the enterprise is less than a certain critical value, the enterprise is unable to obtain loans in time, or there is insufficient financing, we think the enterprise is in financial crisis. Decision tree is a typical machine learning classification algorithm. Each internal node represents the test of the input attribute, the branch derived from the node represents the output of the test, and each leaf node represents the category or class distribution [25].

Decision tree is a hierarchical structure composed of nodes and directed edges. It generally contains three kinds of nodes [26]:

(1) Root node: there are no in edges, but there are zero or more out edges
(2) Internal node: there is exactly one in edge and two or more out edges
(3) Leaf node or endpoint: there is exactly one in edge but no out edge

Starting from the root node of the tree, the test conditions are used to verify the records, and the appropriate branches are selected according to the test results. Follow this branch to another internal node, use new test conditions, or reach a leaf node. After reaching the leaf node, the class item name represented by the leaf node will be assigned to the inspection record.

3.2. Principle Overview of Decision Tree Algorithm. Using the decision tree information mining method, find the most representative attribute in the sample set [10], construct the node of the decision tree, then construct the node of the decision tree according to the attribute value, and analyze the type of the node. If it is an internal node, the node will continue to construct the next node of the decision tree. This is the establishment of decision tree. S sample data exists in set s, and M representative values are set for attribute standards of different categories. D has different categories Xi ($I = 1,\ldots,n$). Let Si be the number of samples in X. Then, for the sample category, the expected information required for differentiation can be expressed as

$$I(S_1, S_2, \ldots, S_m) = -\sum_{i=1}^{m} p_i \log_2(p_i). \quad (1)$$

In the above formula, PI is the probability that any sample belongs to a set and is expressed in Si/s. Let attribute y have v different values {A1,...,AV}. S can be divided into v subsets {S1,...,SV} by attribute y, in which the value of samples in special SJ on attribute y is AJ. Let SIJ be the number of samples of class Xi in subset SJ; then the entropy of attribute y is

$$E(Y) = \sum_{j=1}^{v} \frac{s_{1j} + \ldots + s_{mj}}{s} I\left(s_{1j}, s_{2j}, \ldots, s_{mj}\right). \quad (2)$$

The highest classification accuracy can be obtained by calculating the minimum value of information entropy. For a given subset SJ, $p_{ij} = s_{ij}/s_j$ is the probability that the sample in SJ belongs to Si. And the information gain on attribute y is

$$Gain(Y) = I(s_1, \ldots, s_m) - EY. \quad (3)$$

Therefore, the smaller the value of entropy, the greater the information gain. In terms of practical application, ID3 algorithm is a very valuable classification tool. As a typical case of machine learning in the field of artificial intelligence, it has the advantages of simple algorithm compilation and strong classification ability.

The amount of information I (XI) of the financial risk early warning event Xi can be measured as

$$I(x_i) = -\log_2 p(x_i), \quad (4)$$

where p (x, I) represents the probability of occurrence of event Xi.

Suppose there are m incompatible events $X = \{x_1, x_2, \ldots, x_m\}$. If only one event x occurs, the average information can be measured as

$$I(x_1, x_2, \ldots, x_m) = \sum_{i=1}^{m} I(x_i) = -\sum_{i=1}^{m} P(x_i)\log_2 p(x_i). \quad (5)$$

Assuming that x takes a finite number of variables (x1, X2,...,XM), the information entropy of X can be defined as

$$E(x) = -\sum_{i=1}^{m} P(x_i)\log_a p(x_i). \quad (6)$$

Among them, the logarithmic base a can be a positive task number, usually $a = 2$, and is specified.

The information gain gain (x) of attribute x for classification is

$$Gain(X) = E(S) - E(S|X). \quad (7)$$

Financial gain rate is formed on the basis of information gain. Suppose that attribute X has V different values x1, X2,...,XV, and the training sample s is divided into v subsets S1, S2,...,SV with attribute X. There is a training sample SJ with value XJ on attribute X. It is assumed that the training sample is segmented based on the value of attribute X. Split_Info is the concept of entropy, expressed as

$$Split\_Info(x) = -\sum_{j=1}^{v} p(x_j)\log_2 p(x_i). \quad (8)$$

Then, the information gain rate of the attribute can be expressed as

$$Gain\_Ratio(X) = \frac{Gain(X)}{Split\_Info(X)}. \quad (9)$$

The core of C4.5 algorithm is to generate corresponding test nodes in the decision tree and then divide samples according to attribute values.

4. Analysis of Financial Crisis Early Warning and Risk Control Based on Decision Tree

Table 1 shows the description of the simulated enterprise risk status. The sample data has been discretized based on the decision tree algorithm. According to the risk level of the financial indicators, each financial indicator is divided into four levels: excellent (RL-1), normal (rl-2), low risk (rl-3), and high crisis (rl-4).

It can be seen from Table 1 that the number of category attribute risk status, stability (s), and crisis (c), are 17 and 3, respectively, so the amount of information I (s, c) of the event can be measured as follows:

$$\begin{aligned}
I(s,c) &= -\frac{17}{20}\log_2\frac{17}{20} - \frac{3}{20}\log_2\frac{3}{20} = 0.6098,\\
E(AI) &= -\frac{5}{20}\left(\frac{4}{5}\log_2\frac{4}{5} + \frac{1}{5}\log_2\frac{1}{5}\right) - \frac{7}{20}\left(\frac{6}{7}\log_2\frac{6}{7} + \frac{1}{7}\log_2\frac{1}{7}\right),\\
&\quad -\frac{7}{20}\left(\frac{7}{5}\log_2\frac{7}{5} + \frac{1}{5}\log_2\frac{1}{5}\right) - \frac{1}{20}\left(1\ \log_2\frac{4}{5} + 0\right) = 0.3876,\\
Split_Info(AI) &= -\frac{5}{20}\log_2\frac{5}{20} - \frac{7}{20}\log_2\frac{7}{20} - \frac{1}{20}\log_2\frac{1}{20} = 1.8898,\\
Gain_Ratio(AI) &= \frac{0.6098 - 0.3876}{1.8898} = 0.1176.
\end{aligned} \quad (10)$$

Examine the cash flow ratio of the attribute. When the value is good, the stability is three, and the crisis is zero, the branch can obtain the leaf node stability directly. When the value is normal, the stability is 7, and the crisis is 0, the leaf node crisis can be obtained directly by the branch. The branch must be recalculated when the value is low risk, the stability is 7, and the crisis is 1. When the risk is high, the stability is zero, and the crisis is two, the branch can obtain the leaf node crisis directly. Figure 1 depicts a preliminary decision tree.

As can be seen from Figure 1, the attribute cash flow ratio is the root node, and the training sample data is divided into four subsets: excellent, normal, low risk, and high risk. When the cash flow ratio is low risk, the leaf node cannot be obtained directly. The result is to be determined and needs to be calculated again.

The following will use recursive algorithm to analyze the entropy and information gain rate of other attributes when the value of attribute cash flow ratio is low risk:

$$I(s,c) = -\frac{7}{8}\log_2\frac{7}{8} - \frac{1}{8}\log_2\frac{1}{8} = 0.5436. \quad (11)$$

Attribute financial income A1, and the number of instances with values of excellent, normal, low risk, and high risk is 2, 2, 4, and 0, respectively. When the value is excellent, the stability is 1 and the crisis is 1; when the value is normal, the stability is 2 and the crisis is 0; when the value is low risk, the stability is 4 and the crisis is 0. Then,

$$\begin{aligned}
E(AI) &= -\frac{2}{8}\left(\frac{1}{2}\log_2\frac{1}{2} + \frac{1}{2}\log_2\frac{1}{2}\right) - \frac{2}{8}\left(\frac{2}{2}\log_2\frac{2}{2} + 0\right),\\
&\quad -\frac{2}{8}\left(1\ \log_2\frac{7}{5} + 0\right) - \frac{1}{2}\left(1\ \log_2\frac{5}{5} + 0\right) = 0.2500,\\
Split_Info(AI) &= -\frac{2}{8}\log_2\frac{2}{8} - \frac{2}{8}\log_2\frac{2}{8} - \frac{4}{8}\log_2\frac{4}{8} = 1.5000,\\
Gain_Ratio(AI) &= \frac{0.5436 - 0.2500}{1.5000} = 0.1957.
\end{aligned} \quad (12)$$

Table 1: Simulated enterprise risk status.

Stock abbreviation	Financial income a1	Accounts receivable turnover a8	Quick ratio a19	Cash flow ratio a22	Risk status
Stock 1	Rl-3	Rl-2	Rl-2	Rl-2	Stable
Stock 2	Rl-2	Rl-3	Rl-3	Rl-2	Stable
Stock 3	Rl-1	Rl-3	Rl-2	Rl-2	Stable
Stock 4	Rl-2	Rl-3	Rl-3	Rl-3	Stable
Stock 5	Rl-1	Rl-4	Rl-3	Rl-4	Stable
Stock 6	Rl-3	Rl-4	Rl-4	Rl-3	Crisis
Stock 7	Rl-2	Rl-1	Rl-1	Rl-1	Crisis
Stock 8	Rl-1	Rl-3	Rl-1	Rl-2	Stable
Stock 9	Rl-3	Rl-4	Rl-3	Rl-3	Stable
Stock 10	Rl-2	Rl-2	Rl-2	Rl-4	Stable
Stock 11	Rl-1	Rl-3	Rl-2	Rl-2	Crisis
Stock 12	Rl-1	Rl-4	Rl-2	Rl-3	Stable
Stock 13	Rl-2	Rl-3	Rl-1	Rl-2	Stable
Stock 14	Rl-3	Rl-4	Rl-2	Rl-3	Stable
Stock 15	Rl-2	Rl-3	Rl-1	Rl-2	Stable
Stock 16	Rl-1	Rl-1	Rl-1	Rl-1	Stable
Stock 17	Rl-3	Rl-4	Rl-2	Rl-3	Stable
Stock 18	Rl-1	Rl-3	Rl-4	Rl-1	Stable
Stock 19	Rl-3	Rl-3	Rl-3	Rl-3	Stable
Stock 20	Rl-2	Rl-2	Rl-2	Rl-2	Stable

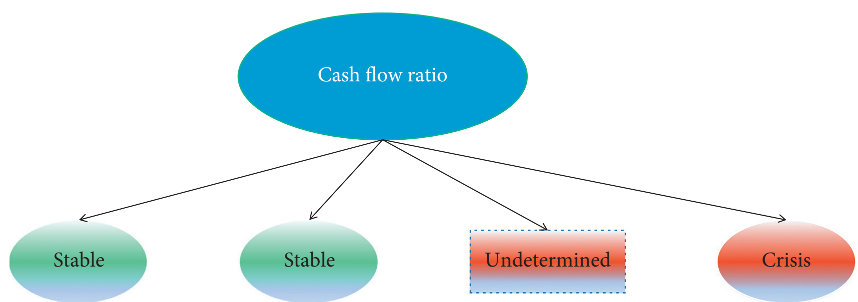

Figure 1: C4.5 algorithm initially forms a decision tree.

Through calculation, compared with the attribute information gain rate, it is obvious that the attribute financial income has the largest information gain rate. When the ratio of cash flow ratio is low risk, financial income is selected as the measurement attribute.

Examine the financial income ratio of the attribute. The branch must be recalculated when the value is good, the stability is 1, and the crisis is 1. When the value is normal, the stability is 2, and the crisis is 0, the leaf node crisis can be obtained directly by the branch. The stability is 4 and the crisis is 0 when the value is low risk. Figure 2 depicts the decision tree created in the second step.

As can be seen from Figure 2, the attribute EPS is the inner node, and the training sample data is divided into four subsets: excellent, normal, low risk, and high risk. When the financial income is excellent, the leaf node cannot be obtained directly, and the result is to be determined, which needs to be calculated for the third time.

Using the same method, the entropy and information gain rate of other attributes are analyzed when the value of financial income is excellent. The result is to select the quick ratio as the test attribute. When the value of the test attribute is low risk, the result is stable; for high risk, the result is crisis. Through the above steps, a complete decision tree is finally obtained, as shown in Figure 3.

The decision tree in Figure 3 uses a specific classification principle to test the data of an unknown mark. If stock *X* and financial income A1 are excellent, accounts receivable turnover A8 is normal, quick ratio A19 is high risk, and cash flow ratio A22 is low risk; then accounts receivable turnover A8 is normal, quick ratio A19 is high risk, and cash flow ratio A22 is low risk. The risk status is crisis, according to the classification of the constructed decision tree.

If the cash flow ratio is good or normal, the risk situation is stable, according to the decision tree. The risk situation is also stable if the cash flow ratio is low risk and the financial income is normal or low risk. Even if the financial income is excellent, if the cash flow ratio is low risk and the quick ratio is high risk, the risk situation is crisis; if the cash flow ratio is high risk, the risk situation is crisis.

5. Analysis of Experimental Results

In order to verify the classification performance of the decision tree model, first test the data set selected by the decision tree algorithm model, then batch calculate, and

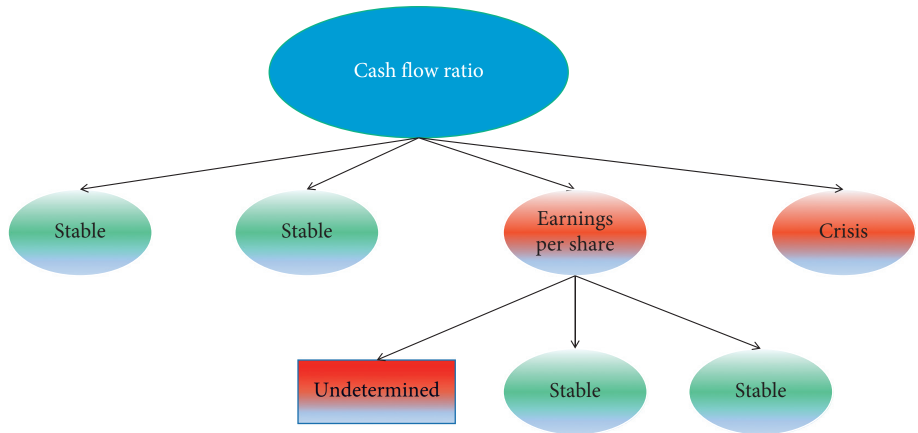

Figure 2: Decision tree formed in the second step of C4.5 algorithm.

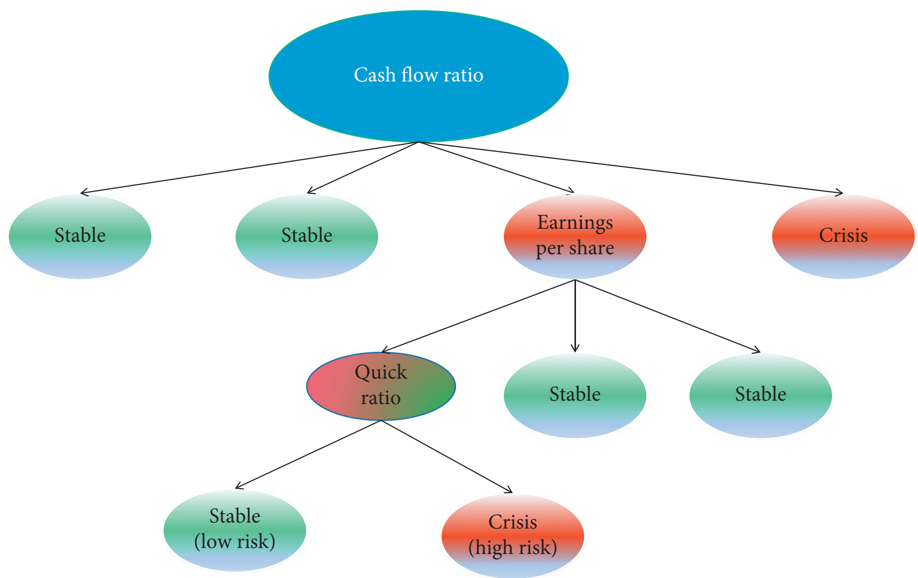

Figure 3: C4.5 algorithm forms a complete decision tree.

compare the test results of the combined classifier. The results of each model value of ratio are shown in Figures 4–10:

The statistical line chart of info value shows the split of the five models. Add a trend line to show the line's approximate trend and the mean value's approximate range. The number of experiments is represented on the horizontal axis, and the split obtained from each experiment is represented on the vertical axis. The lowest value of the longitudinal axis is set to 0.26 and the highest value is set to 0.34 to cover the split obtained by each model. For the info value and to make it easy to compare the linear distribution, the lowest value is set to 0.26 and the highest value is set to 0.34. The split of ID3 model: the average value of info is the lowest, only about 1.4, and its distribution is also the most dispersed among several models, according to the trend lines of the five figures. The split of the decision tree model has improved as the model has improved. The average value of information has increased slightly, but its distribution is similar to that of the ID3 model.

From the image, compared with the first two, the distribution of the broken line graph of the decision tree model is more concentrated, but its mean value has not improved. In contrast, graph (d) is the split obtained from the decision tree single classifier model. The average value of info (obtained by comparing the Split_Info value with the data obtained under all other sampling rates of the model at 100% sampling rate) is close to 0.32, which is the highest among the first four models, that is, the highest among single classifiers, but it still has little change compared with the dispersion of decision tree. Through the integration of classifiers, the decision tree combines the split of classifiers. The average value of info has been further improved, about 00.33. In terms of discreteness, the g value distribution of the model is very concentrated. It can be seen from the figure that the combined model is more stable. The classification effect of info model is the best, there is little difference between different entropy decision tree models, and the classification effect of

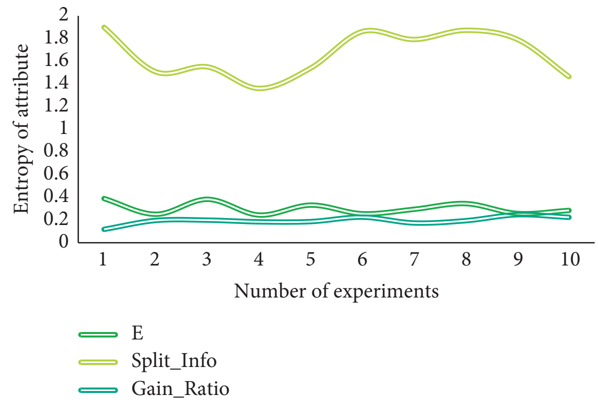

Figure 4: Entropy of decision tree model in the first experiment.

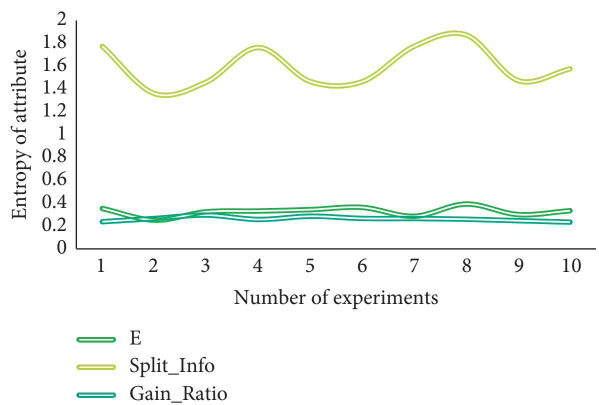

Figure 5: Entropy of decision tree model in the second experiment.

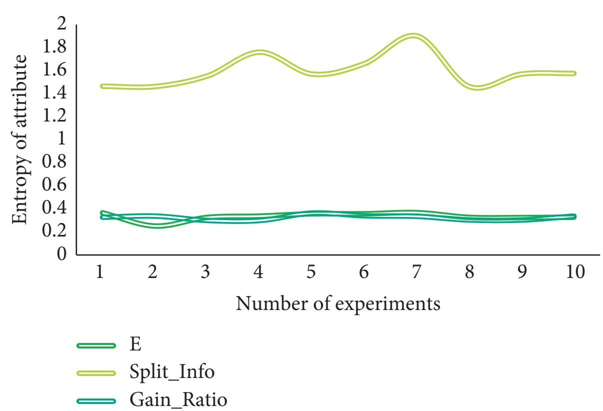

Figure 6: Entropy of decision tree model in the third experiment.

decision tree model is the worst. The integration of combined classifiers significantly improves the classification effect of decision tree model, which can show that the decision tree classifier for the classification problem of unbalanced data sets makes the classification effect better.

On the whole, the total classification accuracy of decision tree model is high, but the performance of other data is very poor, which is not ideal for the prediction of unbalanced bank credit risk [27]; although the distribution of decision tree model in single classifier is relatively concentrated and the classification effect is relatively stable, the low overall classification accuracy makes the model still not ideal. The decision tree combined classifier model of this problem shows great advantages in classification accuracy and stability and has a good effect on the research of credit risk early warning of class unbalanced banks [28].

The results are listed in Tables 2 and 3.

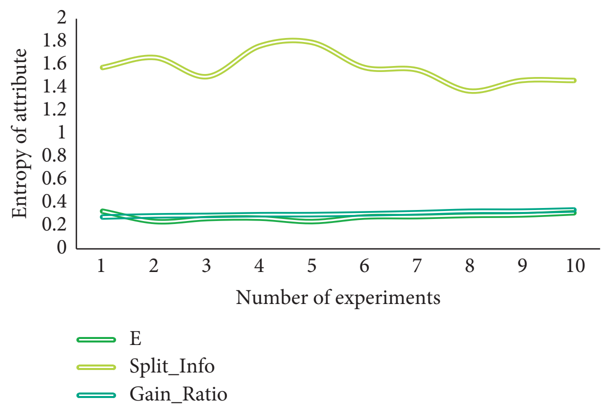

Figure 7: Entropy of decision tree model in the fourth experiment.

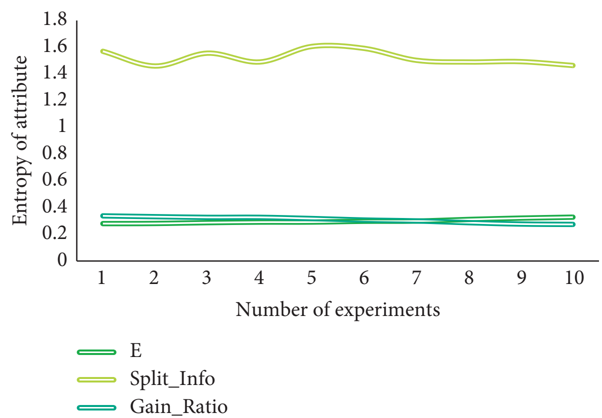

Figure 8: Entropy of decision tree model in the fifth experiment.

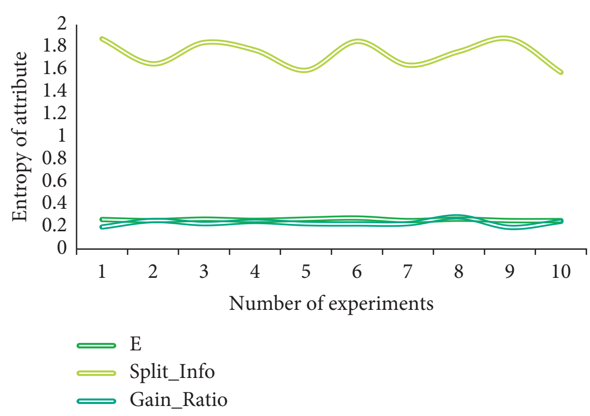

Figure 9: Entropy of decision tree model in the fifth experiment.

The mean difference of info is not significant, while the difference of e-means obtained by the decision tree model is not significant. Furthermore, the mean values of any pair of models differ significantly. The difference in info value is not significant, according to the analysis of each pair of models. The decision tree proposed in this paper is significantly different from other models, particularly the combined decision tree model, demonstrating that the decision tree model proposed in this paper has very superior performance for financial risk early warning data analysis.

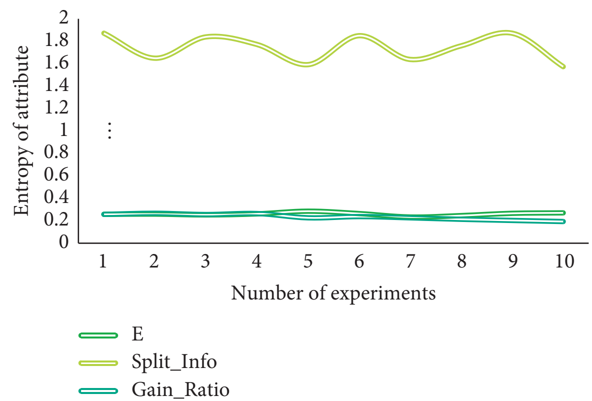

Figure 10: Entropy of decision tree model in the fifth experiment.

Table 2: Decision tree model Split_Info mean paired sample test.

Entropy model	Risk warning level	ID3	OS-ID3	OUS-ID3
ID3	Stable	0.067	0.046	0.000
OS-ID3	Stable		0.837	0.000
OUS-ID3	Risk			0.000

Table 3: Decision tree model Gain Ratio mean paired sample test.

Entropy model	Risk warning level	ID3	OS-ID3	OUS-ID3
ID3	Stable	0.121	0.626	0.000
OS-ID3	Stable		0.157	0.000
OUS-ID3	Risk			0.000

6. Conclusions

People have been unable to use a ratio to obtain enough information to describe all the necessary characteristics of the enterprise, and a single ratio analysis is not only complex, but also difficult for analysts to digest and absorb this information to understand the overall financial situation of the enterprise. By applying the decision tree algorithm financial early warning model to the empirical analysis of enterprises, we can clearly see the effectiveness of the decision tree algorithm early warning model to the Chinese market. The importance of this model is to use multiple variables to obtain information about the financial situation of enterprises. Therefore, it is preferable to combine the financial ratios. In fact, the research on the deterioration of financial situation is not limited to the company. It is more difficult for the company to restructure or reform. It needs a substantial increase in profits to change the current situation. Timely and accurate prediction of financial distress is an essential alarm. Financial risk is the inevitable product of enterprise financial activities, which objectively reflects the operation of enterprises to a certain extent. In the market economy, financial risk exists objectively in every enterprise, especially when the economic system is not perfect, and enterprise financial risk becomes more complex, so the research on enterprise financial risk prevention becomes extremely important.

This paper proposes association rule mining algorithm to analyze enterprise financial risk and decision tree C4.5 algorithm to early warning enterprise financial risk. Although the financial early warning model still lacks a perfect economic theoretical basis and has some problems in methods, it has been highly valued by the practical and academic circles because it plays a good auxiliary role in the decision-making of actual economic activities, even in the current capital market, which is not perfect in all aspects [29].

In the future, the research content of this paper will conduct more in-depth research in the following three aspects:

(1) Explore more effective decision tree algorithm, and find out the data mining method of difficult-to-quantify indicators such as team cooperation and moral hazard
(2) Establish a dynamically maintained enterprise financial crisis early warning model according to the time series, mine the financial indicators for a period of time, adjust the desired mining results, find the frequent patterns and rules of financial crisis early warning indicators that meet the requirements, analyze the final mining results, and summarize the real root causes of enterprise financial crisis
(3) Looking forward to a public enterprise database, the basis of decision tree is to have enough data. Through

the verification of actual data, the research results of this paper will be more meaningful

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Deviation Detection in Clinical Pathways Based on Business Alignment

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Several unexpected behaviors may occur during actual treatment of clinical pathways, which will have negative impact on the implementation and the future work. To increase the performance of current deviation detection algorithms, a method is presented according to business alignment, which can effectively detect the anomaly in the implementation of the clinical pathways, provide judgment basis for the intervention in the process of the clinical pathway implementation, and play a crucial role in improving the clinical pathways. Firstly, the noise in diagnosis and treatment logs of clinical pathways will be removed. Then, the synchronous composition model is constructed to embody the deviations between the actual process and the theoretical model. Finally, $A*$ algorithm is selected to search for optimal alignment. A clinical pathway for ST-Elevation Myocardial Infarction (STEMI) under COVID-19 is used as a case study, and the superiority and effectiveness of this method in deviation detection are illustrated in the result of experiments.

1. Introduction

The data released by the seventh census show that China has gradually entered an aging society. Coupled with the impact of the coronavirus epidemic in recent years, the medical system is facing increasing pressure. Hence, the use of clinical pathway that can regulate medical behavior, improve medical quality, and control medical costs has become an inevitable choice for medical reform in China [1, 2]. With strong national support, the clinical pathway has entered the stage of large-scale promotion [3].

The essence of clinical pathway is to adopt standardized procedures for the diagnosis and treatment of a certain disease. However, in the actual implementation process of clinical pathway, there may be many unstable factors; for instance, patients do not understand the implementation standard of clinical pathway, medical staff are not positive about the process, etc. Factors mentioned above have greatly affected the promotion of clinical pathway. In addition, the imperfection of clinical pathway, including patient condition mutation, may lead to unexpected behaviors in the process of clinical pathway diagnosis and treatment. Such behaviors are all called deviations. Under various pressures, it is urgent to optimize and improve the clinical pathway. Process mining aims to mine and optimize the business process through effective data in event logs [4, 5], and the process mining methods can be used to detect the deviated behaviors, which is beneficial to predict the trend of the patient's diagnosis and treatment process, find the defects in the clinical pathway, and provide judgment basis for the intervention behavior in the diagnosis and treatment process, so as to improve the clinical pathway [6–8].

With the wide application of medical information systems, a large number of electronic logs are generated in the process of diagnosis and treatment, and electronic medical records are also widely used in hospitals. The method of mining deviation behaviors has also changed from a forward-looking method requiring manual recording to a retrospective method automatically processed by computers. This paper establishes the process model of clinical pathway and uses business alignment to detect the deviation between the business process and the execution records.

Lots of formal methods of process model description have been presented up to now, e.g., BPMN [9], C-net [10], EPC [11] and Petri net [12–15]. Petri net is the most mature and in-depth process modeling language, which can concisely and intuitively describe and analyze complex systems [16–27]. Hence, Petri net is selected as the process model description method.

Business alignment is one of the most advanced compliance checking methods at present. The use of business alignment can effectively detect the deviation of clinical pathway [28–30]. Compliance checking of complex models has always been a challenging research topic [31]. Adriansyah et al. [32] presented a technique which combines the process model and log model into a product model to get optimal alignment. Cook et al. [33] presented a means to obtain alignment results by comparing trace and process model with quantifying similarity. Song et al. [34] presented a heuristic trace replay method to align recorded traces and theoretical models, which reduces the search space.

By studying the existing methods, there is still something that can be improved in the efficiency of business alignment. Hence, a business alignment method is presented according to synchronous composition model of Petri nets, which effectively reduces the complexity of the model to improve alignment efficiency. A sequence of events recorded in the medical log of a case is called a trace. There may be some invalid traces in the log, which are called noise. Before the compliance check, it is necessary to filter the diagnosis and treatment logs by preprocessing to remove noise. Deviation detection is to find the optimal alignment based on the filtered treatment logs and locate possible problems in the traces. Since the efficiency of the optimal alignment computation is particularly critical, this paper uses A $*$ algorithm.

The remainder of this paper includes the following. The background knowledge is introduced in Section 2, including the concept of trace, Petri net, reachable graph, and alignment. A noise filter algorithm and an optimal alignment computation algorithm are presented in Section 3. The comparison of the experiments between our method and the classical one is shown in Section 4. Finally, Section 5 draws the conclusion and the ideas of follow-up research.

2. Basic Knowledge

A tremendous amount of data is stored in hospital information systems. We can extract a lot of medical events from them. A series of events in one case is organized as a trace, which is the basic element of logs.

Definition 1 (trace). Given a set A that includes activities, trace is a process instance, namely, a sequence of activities, denoted as $\sigma \in A^*$. If there is a trace of non-empty multiple set $L \in \beta\ (A^*)$, L is called a diagnosis and treatment log, and the set includes each finite sequence on set A, denoted as A^*; the set of all multiple sets on set A^* is denoted as $\beta\ (A^*)$.

Definition 2 (Petri net). Given a set A that includes activities, Petri net is a tuple on set A, denoted as $N = (P, T; F, \alpha, m_i, m_f)$. Set P contains all places, and set T contains all transitions, where $T \cup P \neq \varnothing$, $T \cap P = \varnothing$; set $F \subseteq (T \times P) \cup (P \times T)$ represents the directed arc set of the relationship between the place and the transition, which is called the flow relationship or arc relationship; $\alpha{:}T \longrightarrow A^\tau$ is the mapping function of transition and label, and τ is the invisible transition, that is, $A^\tau = A \bigcup \{\tau\}$; the state of Petri net is named as marking, which is a multiple set of the place set. $m_i \in \beta\ (P)$ stands for the initial state, and $m_f \in \beta\ (P)$ stands for the final state.

A simple Petri net example N_1 for clinical pathway of ischemic stroke is shown in Figure 1, and Table 1 shows the relationship of transitions, labels, and activities in model N_1.

For $\forall m \in \beta\ (P)$ and $\forall t \in T$, t can be fired under marking m iff $m\ (p) \geq \forall_{p \in P} F\ (p,\ t)$ holds, represented as $m\ [t>$; at this time, after the transition t occurs, the new state of the system denotes as m', and $\forall_p \in {}_P m'\ (p) = m\ (p) - F\ (p,\ t) + F\ (t,\ p)$, represented as $m\ [t > m'$. The set $R\ (m)$ contains all the markings which can be enabled under m.

The definition of Petri net's reachable graph can be constructed by the transition firing rule in Definition 2.

Definition 3 (reachable graph). Given a Petri net N, reachable graph of N is represented as $TS = (S, A', T')$, where $S = R\ (m_i)$, $A' = A$, $T' = \{(m_i,\ \alpha\ (t),\ m_j) \in (S \times A \times S) |\ \exists_{t \in T}\ (m_i [t > m_j])\}$.

Figure 2 shows the reachable graph TS_0 of N_1. Every node in the graph stands for a reachable marking of N_1, every arc means a transition that is enabled under its previous marking, and arrow points to the new marking after transition occurs.

When the trace in the diagnosis and treatment log is replayed on the model, the two may not be completely fitted. This unfit state is called deviation which can be detected by alignment.

Definition 4 (alignment) Given a set A including activities, a Petri net N, and a trace σ, the alignment between σ and A, namely, $\gamma \in (A{\gg} \times T{\gg})^*$ is a moving sequence (where $\gg$ denotes no movement and $A{\gg} = A \cup \{\gg\}$) which has the following rules:

(1) The projection of the first column elements in the ordered set of movements on A (ignoring $\gg$) is recorded as $\pi_1\ (\gamma)_{\downarrow A} = \sigma$.

(2) The projection of the second column elements in the ordered set of movements on T (ignoring $\gg$) produces a complete firing sequence, denoted as $m_i \longrightarrow^{\pi_2}\ (\gamma)_{\downarrow T}\ m_f$.

For every $(a,\ t) \in \gamma$, there are four possibilities:

(1) $(a,\ t)$ is named as log movement in case of $(a \in A) \wedge (t = \gg)$.

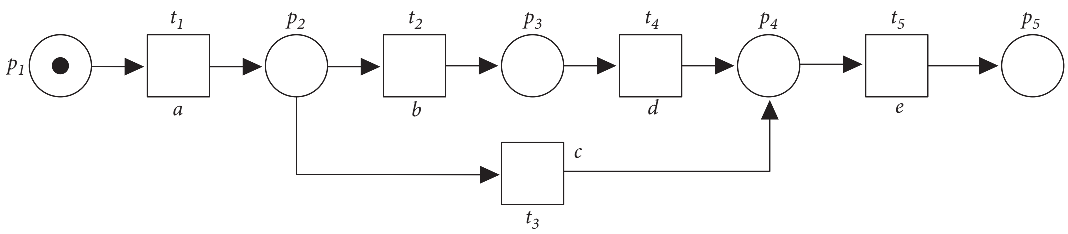

FIGURE 1: Petri net N_1 for clinical pathway of ischemic stroke.

TABLE 1: The relationship between transitions and activities of model N_1.

Transition	Label	Activity	Transition	Label	Activity
t_1	a	Initial inspection	t_4	d	Thrombolytic therapy
t_2	b	Meeting thrombolytic inclusion criteria	t_5	e	Hospitalization
t_3	c	Meeting thrombolytic exclusion criteria			

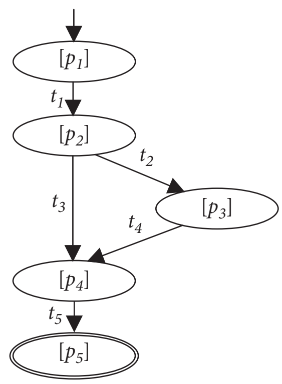

FIGURE 2: Reachable graph TS_0 for N_1.

(2) (a, t) is named as model movement in case of $(a = \gg) \wedge (t \in T)$.

(3) (a, t) is named as synchronous movement in case of $(a \in A) \wedge (t \in T)$.

(4) (a, t) is named as illegal movement.

Activity is an element of traces, and transition is an element of model. According to Definition 4, alignment is a sequence of movements, and movement reflects the correlation between the activities and transitions. For log movement, it means that an activity cannot be executed in the model; for model movement, it means that a transition is not observed in the trace; for synchronous movement, it means that the activity can correspond to the transition; for illegal movement, it will not occur in actual business process, so it will be ignored in this paper. Among them, (1) and (2) are the unfitness between trace and process model, which represent the deviations in alignment.

For a given trace and a process model, multiple alignment results may be computed. To get the best alignment result, a cost function needs to be introduced to compute the cost of each movement. Among all the alignment results, the alignment with the minimum total cost value is the optimal alignment.

For every $(a, t) \in \gamma$, the cost function is as follows:

(1) The value of $lc((a, t))$ is 1, when (a, t) is log movement.

(2) The value of $lc((a, t))$ is also 1, when (a, t) is model movement.

(3) The value of $lc((a, t))$ is 0, when (a, t) is synchronous movement.

(4) The value of $lc((a, t))$ is $+\infty$, when (a, t) is illegal movement.

3. Alignment Methods

3.1. Preparation for Alignment Computation

3.1.1. Removal of Noise. Before the implementation of synchronous composition, it is necessary to filter the traces in the diagnosis and treatment log, remove the noise, and retain effective traces.

There are generally two possibilities for traces with sequential deviation in event logs: ① the trace itself is noise and ② the activity which should occur in sequential relationship or selection relationship occurred in parallel relationship incorrectly. In the clinical pathway, it must be strictly in accordance with the implementation standards of clinical pathway, and the activities are mostly sequential or selective. Hence, traces with inverted sequence activities are considered as noise in this paper.

In Petri net, when a transition can occur before other transitions, there is a precedence relationship between this transition and its subsequent transitions, which is denoted by the symbol "⟶." When a transition cannot occur before others, there is no precedence relationship between this transition and others, which is denoted by the symbol "#." For the possible sequential deviation traces in the diagnosis and treatment log, this paper presents the concept of precedence relationship matrix as follows.

Definition 5. (precedence relationship matrix). Given a set A including activities and a Petri net N, the precedence relationship matrix is a matrix of $|T|\times|T|$, whose row and column labels are the activities, denoted as $M{:}\{\alpha(t_x)|t_x\in T\}\times\{\alpha(t_y)|t_y\in T\}\longrightarrow\{\text{"\#," "}\longrightarrow\text{"}\}$. The matrix contains the following elements:

(1) For any $\alpha(t_x)\in S$ and $\alpha(t_y)\in S$, if $\exists<t_1,\ldots,t_x,\ldots,t_y,\ldots,t_n>$, $m_{\mathrm{i}}\longrightarrow^{t_1}\ldots t_x\ldots t_y\ldots t_n\,m_{\mathrm{f}}$, then $M[\alpha(t_x)][\alpha(t_y)]=$ "⟶," denoted as $\alpha(t_x)\longrightarrow\alpha(t_y)$, where $1\le x$, $y\le n$.

(2) For any $\alpha(t_x)\in S$ and $\alpha(t_y)\in S$, if $\nexists<t_1,\ldots,t_x,\ldots,t_y,\ldots,t_n>$, $m_{\mathrm{i}}\longrightarrow^{t_1}\ldots t_x\ldots t_y\ldots t_n\,m_{\mathrm{f}}$, then $M[\alpha(t_x)][\alpha(t_y)]=$ "#," denoted as $\alpha(t_x)\#\alpha(t_y)$, where $1\le x$, $y\le n$.

Take N_1 as an example, and its precedence relationship matrix M_{pr} is shown in formula (1), where $a_x=\alpha(t_x)$ and $1\le x\le 5$.

$$M_{\mathrm{pr}}=\begin{array}{c}\\ a_1\\ a_2\\ a_3\\ a_4\\ a_5\end{array}\begin{array}{c}\begin{array}{ccccc}a_1 & a_2 & a_3 & a_4 & a_5\end{array}\\ \begin{bmatrix}\# & \longrightarrow & \longrightarrow & \longrightarrow & \longrightarrow\\ \# & \# & \# & \longrightarrow & \longrightarrow\\ \# & \# & \# & \# & \longrightarrow\\ \# & \# & \# & \# & \longrightarrow\\ \# & \# & \# & \# & \#\end{bmatrix}\end{array}. \quad (1)$$

To determine whether a trace is noise, it is necessary to check all activities in the trace one by one and compare the order between the current activity and its subsequent activities by the precedence relationship matrix. If not fitting, the comparison process is terminated, and the trace is regarded as noise, which should be removed from the log.

To store information of parallel activities, it is necessary to set a parallel activity set S as "current activity set" to compare with their subsequent activities, and the first activity in the trace is put into S before starting the traversal. Meanwhile, several variables are set as follows: let the current activity in traversal be activity *cur* and the subsequent activity in trace be activity *post*. The rules are as follows:

(1) If there is one or more activities that precedence relationship matrix allow to occur earlier than activity *post* in the set S and otherwise do not hold, remove these activities from the set S and place activity *post* in the set S.

(2) If all activities in the set constitute the parallel relationship with activity *post*, then put activity *post* in the set S without removing any other element.

(3) If there is an inverted sequence deviation between any activity and activity *post* in set S, this trace is regarded as noise and should be abandoned directly.

Algorithm 1 shows the pseudocode.

To filter the log, it is necessary to traverse the diagnosis and treatment log L and then gradually check the activities in the sequence σ, so two nested loops are required. $O(n^2)$ is its time complexity. The value of n is affected by the size of L and the length of the sequence σ. The space complexity is $O(n)$.

3.1.2. Synchronous Composition. For a given trace and its corresponding process model, a new model can be generated by the following operations: ① convert the trace into the log model described by Petri net; ② merge two corresponding transitions with the same activity label in two models; and ③ merge presets and postsets of the same transitions, respectively. Finally, the generated model is the synchronous composition model of trace and process model.

The log model transition and process model transition with the same label x will construct synchronous movement. For other synchronous movements, the transitions should be named according to Definition 4. Algorithm 2 shows the pseudocode.

The algorithm integrates the transitions, places, and arc relationships of process model N_{pm} and log model N_{lm} into synchronous composition model N_3. There are three loop structures, so $O(n)$ is the time complexity. The quantity of transitions, places, and the arc relationships affect the size of n, so space complexity is $O(n)$.

Taking N_1 as an example, trace $\sigma_1=<a, f, b, e>$ is given. Figure 3 shows the log model N_2 which is converted from σ_1. The synchronous composition model N_3 computed by Algorithm 2 from log model N_2 and process model N_1 is shown in Figure 4.

3.2. Computation of Alignment

3.2.1. Reachable Graph of Synchronous Composition Model. Since alignment is a sequence of movements, the transitions occur with the change of states and reachable graph can clearly express the changes of states and occurred transitions, and a weight can be given to every arc of a reachable graph to represent the cost of the occurred transition. The computation of optimal alignment can be converted to find the shortest path of a directed weighted graph, so the reachable graph of N_3 is then computed. The reachable graph TS_1 of N_3 is shown in Figure 5.

It can be inferred from Definition 4 that (t_1', t_1) is a synchronous movement, so $lc((t_1', t_1))=0$; $(\gg, t_3)$ is a model movement, so $lc((\gg, t_3))=1$; $(t_2', \gg)$ is a log movement, so $lc((t_2', \gg))=1$. By analogy, it can be obtained that the values of the other transitions in Figure 5 are $lc((t_3', t_2))=0$, $lc((\gg, t_4))=1$, $lc((t_4', t_5))=0$.

Input: diagnosis and treatment log L, precedence relationship matrix M of N_1;
Output: filtered log L'.

$S = \varnothing$;
$L' = L$;
for all $\sigma \in L'$ **do**
  $S = S \cup \{\sigma\ (1)\}$;
  for all $cur \in \sigma$ **do**
    //terminate if current activity is the last one
    if $\sigma.indexOf\ (cur) == \sigma.size - 1$ **then**
      break;
    end
    $post = \sigma\ (\sigma.indexOf\ (cur) + 1)$;
    if $(\exists a \in S) \Rightarrow (M\ [\alpha^{-1}\ (a)][\alpha^{-1}(post)] ==$ “#”) **then**
      $L' = L' - \{\sigma\}$;
      //activity a can occur earlier than activity $post$, but the reverse is not true
    else if $(\exists a \in S) \Rightarrow (M\ [\alpha^{-1}\ (a)][\alpha^{-1}(post)] ==$ “$\longrightarrow$” && $M\ [\alpha^{-1}(post)][\alpha^{-1}(a)] ==$ “#”) **then**
      for all $(a \in S) \wedge (M\ [\alpha^{-1}(a)][\alpha^{-1}(post)] ==$ “$\longrightarrow$” && $M\ [\alpha^{-1}(post)][\alpha^{-1}(a)] ==$ “#”) **do**
        $S = S - \{a\}$;
      end
      $S = S \cup \{post\}$;
    else
      $S = S \cup \{post\}$;
    end
  end
  $S = \varnothing$;
end
return L';

Algorithm 1: The noise filter algorithm.

Input: process model N_{pm}, log model N_{lm};
Output: synchronous composition model N_{cm}.

$P_{\mathrm{cm}} = P_{\mathrm{pm}} \cup P_{\mathrm{lm}}$;
$F_{\mathrm{cm}} = \varnothing$;
$T_{\mathrm{cm}} = \varnothing$;
$m_{i,\mathrm{cm}} = m_{i,\mathrm{pm}} \cup m_{i,\mathrm{lm}}$;
$m_{f,\mathrm{cm}} = m_{f,\mathrm{pm}} \cup m_{f,\mathrm{lm}}$;
for all $t'_x \in T_{\mathrm{lm}}$ **do**
  //place transitions in T_{cm} according to T_{lm};
  $T_{\mathrm{cm}} = T_{\mathrm{cm}} \cup \{(t'_x, \gg)\}$;
  //set the related mapping functions and arc relations
  $\alpha_{\mathrm{cm}}\ ((\gg, t_y)) = \alpha_{\mathrm{pm}}\ (t_y)$;
  $F_{\mathrm{cm}} = F_{\mathrm{cm}} \cup \{(p, (\gg, t_y)) | p \in {}^{\bullet}t_y \wedge t_y \in T_{\mathrm{pm}}\} \cup \{((\gg, t_y), p) | p \in t_y^{\bullet} \wedge t_y \in T_{\mathrm{pm}}\}$;
end
for all $t_y \in T_{\mathrm{pm}}$ **do**
  //place transitions in T_{cm} according to T_{pm};
  $T_{\mathrm{cm}} = T_{\mathrm{cm}} \cup \{(\gg, t_y)\}$;
  //set the related mapping functions and arc relationships
  $\alpha_{\mathrm{cm}}\ ((\gg, t_y)) = \alpha_{\mathrm{pm}}\ (t_y)$;
  $F_{\mathrm{cm}} = F_{\mathrm{cm}} \cup \{(p, (\gg, t_y)) \mid p \in {}^{\bullet}t_y \wedge t_y \in T_{\mathrm{pm}}\} \cup \{((\gg, t_y), p) \mid p \in t_y^{\bullet} \wedge t_y \in T_{\mathrm{pm}}\}$;
end
for all $t'_x \in T_{\mathrm{lm}} \wedge t_y \in T_{\mathrm{pm}} \wedge \alpha_{\mathrm{lm}}\ (t'_x) == \alpha_{\mathrm{pm}}\ (t_y)$ **do**
  //place synchronous transitions in T_{cm};
  $T_{\mathrm{cm}} = T_{\mathrm{cm}} \cup \{(t'_x, t_y)\}$;
  //remove log transitions and model transitions with the same labels;
  $\alpha_{\mathrm{cm}}\ ((t'_x, t_y)) = \alpha_{\mathrm{cm}}\ (t'_x, \gg)$;
  $T_{\mathrm{cm}} = T_{\mathrm{cm}} - \{(t'_x, \gg), (\gg, t_y)\}$;

Algorithm 2: Continued.

//set the related mapping functions and arc relationships of the new transitions; remove the related arc relationships of the removed transitions of the deleted transitions
$F_{cm} = F_{cm} \cup \{((t'_x, t_y), p') | p' \in (t'_x, \gg)^{\bullet}\} \cup \{(p', (t'_x, t_y)) | p' \in {}^{\bullet}(t'_x, \gg)\}$;
$F_{cm} = F_{cm} - \{((t'_x, \gg), p') | p' \in (t'_x, \gg)^{\bullet}\} - \{(p', (t'_x, \gg)) | p' \in {}^{\bullet}(t'_x, \gg)\}$;
$F_{cm} = F_{cm} \cup \{((t'_x, t_y), p) \mid p \in (\gg, t_y)^{\bullet}\} \cup \{(p, (t'_x, t_y)) \mid p \in {}^{\bullet}(\gg, t_y)\}$;
$F_{cm} = F_{cm} - \{((\gg, t_y), p) \mid p \in (\gg, t_y)^{\bullet}\} - \{(p, (\gg, t_y)) \mid p \in {}^{\bullet}(\gg, t_y)\}$;
end
return $N_{cm} = (P_{cm}, T_{cm}; F_{cm}, \alpha_{cm}, m_{i,cm}, m_{f,cm})$;

Algorithm 2: Synchronous composition algorithm.

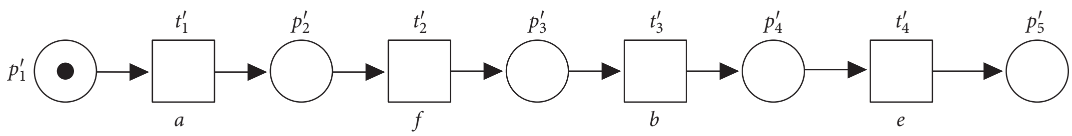

Figure 3: Log model N_2.

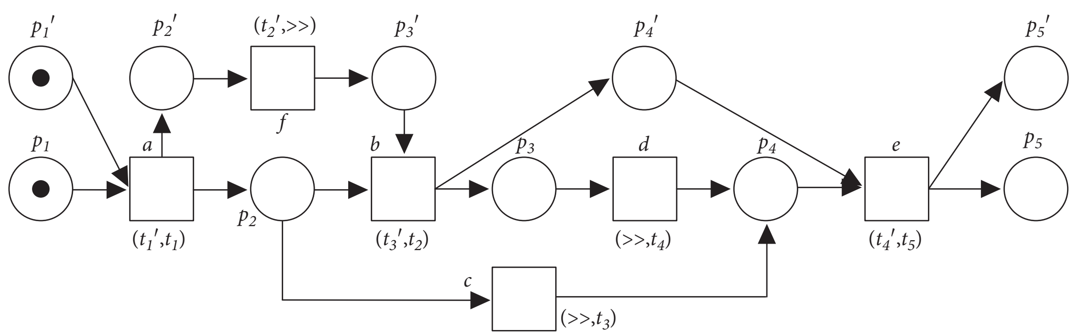

Figure 4: Synchronous composition model N_3.

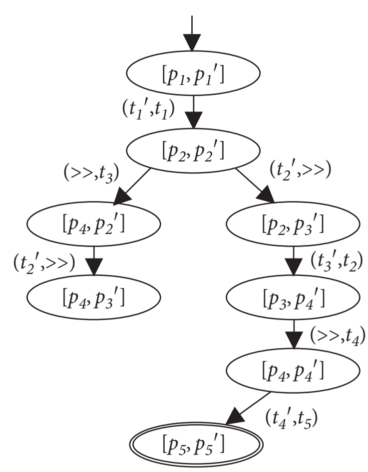

Figure 5: Reachable graph TS_1 of N_3.

3.2.2. Search for Optimal Alignment. Considering the particularity of the clinical pathway model, the sequential and selective structure should be used as far as possible in this kind of model and the cyclic structure should be avoided. Hence, the cyclic structure in the reachable graph of the model will be ignored, and the graph can be easily converted into the form of relationship matrix. It can be seen that the optimal alignment computation is not complicated, and the efficiency is one of the key performance measures. Hence, it is necessary to select appropriate search algorithms to maximize efficiency.

As mentioned earlier, the optimal alignment problem is also the shortest path problem. Among the solutions to the shortest path problem, the basic search algorithms (e.g., the depth-first algorithm, the breadth-first algorithm, and the Dijkstra algorithm) are well known with simple structure and easy implementation. However, in dealing with this problem, it is necessary to traverse paths one by one, and the efficiency is poor. The intelligent algorithms (e.g., genetic algorithm, reinforcement learning algorithm, and ant colony algorithm) are too complex and need to be trained through a large number of datasets to adjust parameters, which is suitable for solving the tricky issues in complex scenes and is not suitable for solving this problem.

Since the weight of each arc is known, $A*$ algorithm is suitable for this problem, which is a famous heuristic algorithm. When solving the shortest path, $A*$ algorithm will estimate the distance between the current node and the target node. The accuracy of the heuristic function will affect the efficiency of $A*$ algorithm, and the accuracy represents the proximity between the estimated and the actual value. In addition, the code implementation of $A*$ algorithm is simple. Since the estimated value computed by the cost function used in this paper is basically equal to the actual value, the computational efficiency can reach the highest level. For reachable graph TS_1 obtained in Section 3.2.1, Algorithm 3 shows the pseudocode.

Considering that the algorithm uses the priority queue, assuming that it uses quick sort, $O\ (n\log_2{}^n)$ is the time complexity, and the quantity of reachable markings affects the size of n. In Algorithm 3, the frequency of iterations is affected by the complexity of the reachable graph, too. Hence, the time complexity is $O\ (n^2\log_2{}^n)$, and the space complexity is $O\ (n)$.

Taking reachable graph TS_1 as an example, formula (2) is the result of optimal alignment.

$$\gamma_1 = \begin{array}{|c|c|c|c|c|} \mathrm{a} & \mathrm{f} & \mathrm{b} & \gg & \mathrm{e} \\ \mathrm{a} & \gg & \mathrm{b} & \mathrm{d} & \mathrm{e} \\ t_1 & & t_2 & t_4 & t_5 \end{array} \qquad (2) \qquad (2)$$

Algorithm 3 finds the optimal alignment by calculating the minimum sum cost value of the occurred transition sequences. In the implementation of the algorithm, it is not necessary to generate reachable graph of synchronous composition model. The synchronous composition model can be directly used as the input to generate the search space, which can simplify the solving step, save the processing time, and improve the computational efficiency.

4. Experiment Analysis

4.1. Experiment Settings. This experiment will compare the scale of the model and the efficiency of alignment. There are three main elements to measure the scale of the model, including

(1) Quantity of places: how many places there are in the model. In general, the less the number, the lower the complexity.

(2) Quantity of transitions: how many transitions there are in the model. In general, the less the number, the lower the complexity.

(3) Quantity of arcs: how many arc relationships there are in the model. In general, the less the number, the lower the complexity.

The factors that measure alignment efficiency are the time consumed and the memory space occupied by the process of optimal alignment computation. In this experiment, the memory occupancy is measured by the quantity of reachable markings generated in the process of running Petri net. Hence, there are two main factors to measure the alignment algorithm:

(1) Quantity of reachable markings (quantity of queued nodes): how many reachable markings generated there are when the model is running. When calculating the optimal alignment, the number is equal to the quantity of the nodes queued in the priority queue, which is also called as the quantity of queued nodes.

(2) Computation time: the time consumed when computing the optimal alignment.

For a given process model, a log set, and a cost function, the computation process of the optimal alignment which presented by Adriansyah et al. can be divided into two steps: first, generate the search space; then, search for the optimal alignment. The reachable graph of the new-generated model is considered as the search space, whose complexity can be measured by the scale of the new model and basically determine the cost of the entire optimal alignment computation method. This experiment focuses on this part. Similarly, the method in this paper uses $A*$ algorithm for optimal alignment computation. Theoretically, this method reduces unnecessary transitions and arcs, so the quantity of reachable markings is less, and the efficiency should be better than the classical one when computing the optimal alignment.

Next, the clinical pathway of ST-Elevation Myocardial Infarction (STEMI) under COVID-19 is taken as an example for experimental verification. The model is manually established according to the natural language description of the diagnosis and treatment process. The specific clinical pathway is shown in Figure 6, and the relationship between activities and transitions is shown in Table 2.

The main work of this experiment is to compare the scale of the search space and efficiency of the alignment computation between the classical method and the method presented in this paper. All the fitting traces in logs are generated from the running process model, then noise is added in the proportion of the deviation number to the length of the trace from 0% to 30%, and each 5% is a group. Each trace is dealt with by Algorithm 3 and the classical algorithm for 10 times, respectively. The mean computation time and model scale parameters are obtained, so as to fully compare the differences between the two under the premise of control variables.

4.2. Experimental Environment. The experiment code adopts Java language, and Table 3 shows the hardware and software platform configuration.

4.3. Algorithm Superiority Verification. The results are shown in Figures 7–10. Among them, Figures 7 and 8 show the

```
Input: reachable graph TS of synchronous composition model N3;
Output: optimal alignment γ.
  //initialize a priority queue by (total cost value of m_i to m_f) + (total estimated value of the current node to the target node) in ascending order
  pqueue.create ();
  visitedNodesSet = Ø;
  pqueue.push (TS.initialmarking);
  while pqueue.size ()! = 0 do
    currenrNode = pqueue.poll ();
    if currenrNode == targetNode then
    //recursively search the predecessor node of currenrNode to get optimal alignment
    γ = getOptAlignment (currenrNode);
    return γ;
    else
      //visit all successorNodes of currentNode
      for all successorNode ∈ currentNode.getSuccessors() do
        //calculate the new total cost value of successorNode
        newcost = successorNode.calNewCost (currentNode);
        if successorNode ∈ visitedNodesSet then
          //for the visited node, if the new total cost value is smaller, update the total cost value of successorNode
          if successorNode.getTotalCost() > newcost then
            successorNode .setTotalCost (newcost);
            pqueue.push (successorNode);
          end
        Else
          visitedNodesSet = visitedNodesSet ∪ {successorNode};
          successorNode.setTotalCost (newcost);
          pqueue.push (successorNode);
        end
      end
    end
  end
```

Algorithm 3: Optimal alignment algorithm based on A ∗ algorithm.

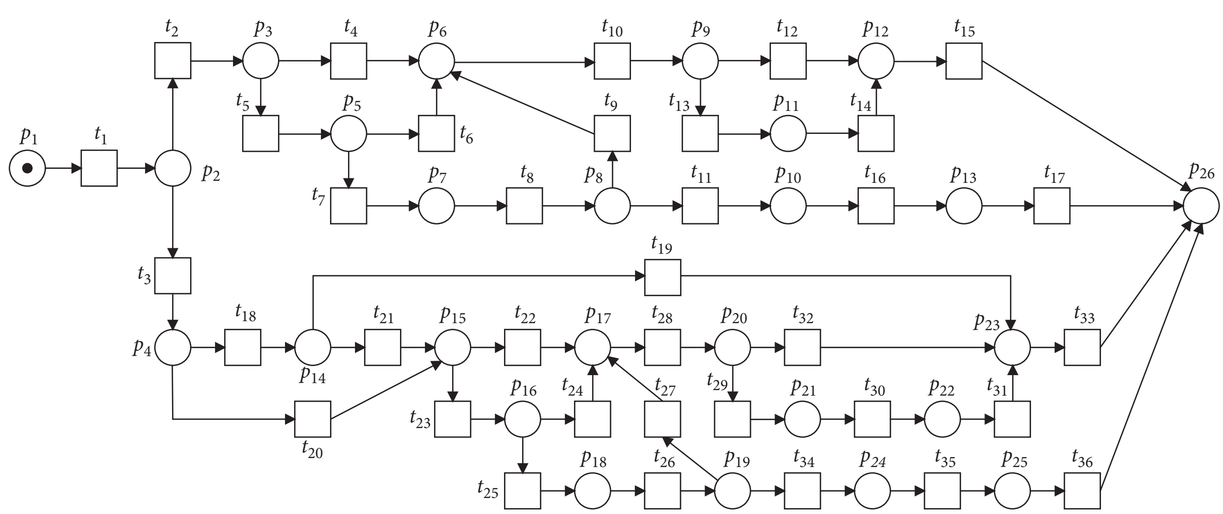

Figure 6: Clinical pathway of STEMI under COVID-19.

comparison of the scale parameters of the two generated models. Figure 9 shows the comparison of the mean queued node number of the two models, and Figure 10 shows the comparison of the mean computation time of the two methods.

This paper does not give a comparison on the quantity of places between the two models because when the trace length and the process model are the same, the quantity of places in the two models is the same, too. Comparing the

Table 2: The relationship between activities and transitions of Figure 6.

Transition	Activity	Transition	Activity
t_1	Medical history/body temperature/ECG/chest CT/blood sample collection	t_{19}	Symptoms mainly with COVID-19
t_2	Exclusion of COVID-19 infection	t_{20}	Stable vital signs
t_3	Suspected or confirmed COVID-19 infection complicated with STEMI	t_{21}	Symptoms mainly with STEMI
t_4	Onset time of STEMI in emergency patients > 12 h	t_{22}	Onset time of STEMI in COVID-19 patients > 12 h
t_5	Onset time of STEMI in emergency patients ≤ 12 h	t_{23}	Onset time of STEMI in COVID-19 patients ≤ 12 h
t_6	Emergency patients with contraindications to thrombolysis	t_{24}	Contraindications to thrombolysis (COVID-19)
t_7	Emergency patients without contraindications to thrombolysis	t_{25}	No contraindications to thrombolysis (COVID-19)
t_8	CCU thrombolysis	t_{26}	Thrombolytic therapy (isolation ward)
t_9	No recanalization of thrombolysis in emergency patients	t_{27}	No recanalization of thrombolysis in COVID-19 patients
t_{10}	Assessment of STEMI patient's benefits and risks	t_{28}	Assessment of STEMI and COVID-19 patient's benefits and risks
t_{11}	Recanalization of thrombolysis in emergency patients	t_{29}	STEMI patient's benefits with COVID-19 > risks
t_{12}	STEMI patient's benefits ≤ risks	t_{30}	Start-up of protection scheme
t_{13}	STEMI patient's benefits > risks	t_{31}	COVID-19 isolation catheter room for PCI
t_{14}	Isolation catheter room for PCI	t_{32}	STEMI patient's benefits with COVID-19 ≤ risks
t_{15}	Continuing treatment in CCU	t_{33}	Isolation ward conservative treatment
t_{16}	CCU conservative treatment	t_{34}	Recanalization of thrombolysis in COVID-19 patients
t_{17}	Selective intervention	t_{35}	Continuing treatment in CCU"
t_{18}	Unstable vital signs	t_{36}	Selective intervention after COVID-19 recovery

Table 3: Experimental environment.

PC model	Lenovo 82JQ
CPU	R7-5800H (3.2 GHz)
Memory	16 GB
OS	Windows10
JDK version	1.8

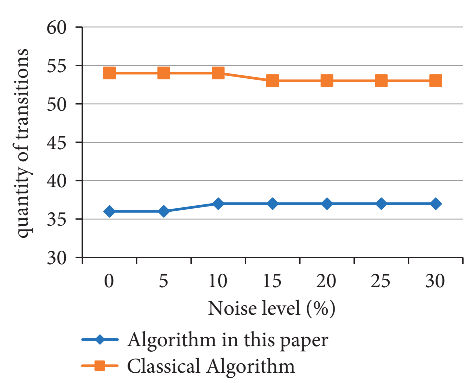

Figure 7: Comparison of the quantity of transitions with different noise levels between two models.

product model in classical algorithm and synchronous composition model in this paper, the quantity of places in the two models is equal to the element number of the union of places in the log model and process model.

Figure 7 compares the quantity of transitions between the two models. The number in the synchronous composition model is about 37, and the number in the product model is about 54. The synchronous composition model reduces some unnecessary transitions, which greatly decreases the scale of the model.

Figure 8 shows the comparison about the quantity of arcs between the two models. The number in the synchronous composition model is about 92, and the number in the product model is about 125. Arc is the flow relationship explained in Definition 2, which indicates the relationship between the transition and the place. The synchronous

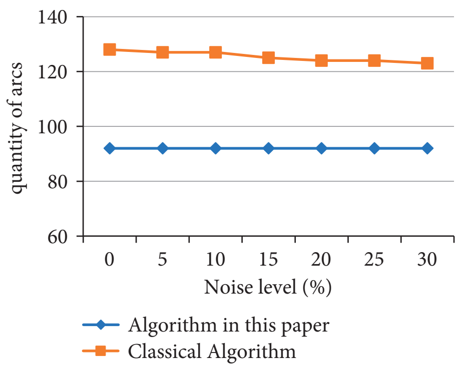

Figure 8: Comparison of the quantity of arcs with different noise levels between two models.

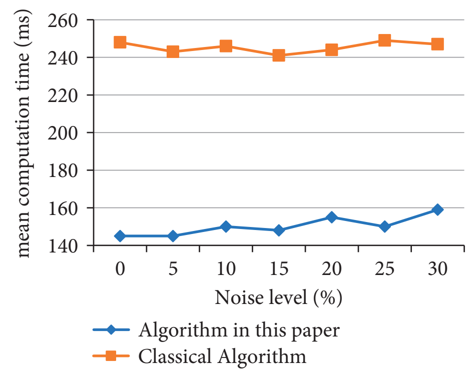

Figure 10: Comparison of the mean computation time with different noise levels between two algorithms.

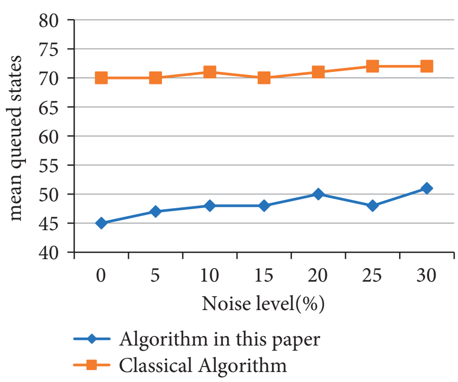

Figure 9: Comparison of the mean queued states (reachable markings) with different noise levels between two models.

composition model not only reduces transitions but also reduces some unnecessary flow relationships, so it reduces the complexity of the search space.

In the part of the optimal alignment computation, Figure 9 shows the quantity of reachable markings in reachable graphs of two models, i.e., mean queued nodes in the optimal alignment computation process. The number in the synchronous composition model is about 47, and the number in the product model is about 72. The quantity of reachable markings affects the time of iteration and sorting efficiency of A $*$ algorithm, as shown in Algorithm 3.

In Figures 7 and 8, the synchronous composition model reduces unnecessary transitions and arcs compared with product model, which makes the reachable graph closer to the real situation and reduces the unnecessary reachable markings.

Figure 10 compares the mean computation time of the two methods in finding the optimal alignment. The mean computation time of Algorithm 3 is about 150 ms, while the time of the classical algorithm is about 245 ms. It saves about 40% of the time and can complete the computation of optimal alignment faster than the classical algorithm at each noise level.

It can be seen from the data that the synchronous composition model used in this paper has lower complexity and higher computational efficiency. Next, the reasons are analyzed and explained.

First of all, the method presented in this paper preprocesses the log when generating the search space and removes noise. This step is also an indispensable step because this method is designed for clinical pathway, which can effectively filter unreasonable noise to prevent the algorithm from failure. Preprocessing is carried out for the log with low time complexity. Even if it cannot be directly reflected from the data, there is a subtle influence on the alignment efficiency and algorithm stability. The product model used in classical method has no need to do this operation because its higher complexity allows it to adapt to more situations at the cost of efficiency. Even if noise can be filtered by such preprocessing, it will not affect the stability of the classical algorithm and has little effect on the efficiency improvement.

Secondly, when generating the search space, the product model will keep the two kinds of original transitions, but the synchronous composition model will not. Assuming that the sum of the transitions in the log model and process model is t, the sum of the arcs is f, and the quantity of synchronous activities is s (assuming that the sum of the flow relationships associated with the log transition and the model transition corresponding to the i-th synchronous activity is f_i); in the product model, the quantity of corresponding transitions is $t+s$, and the quantity of arcs is $f + \sum_{i=1}^{s} f_i$; in the synchronous composition model, the quantity of transitions is $t-x$, and the quantity of arcs is f. That is, each synchronous activity will make product model have 2 more transitions and several arcs than the synchronous composition model. These additional transitions and arcs have no actual meaning. The preprocessing step of this method solves the problem in advance and simplifies the scale of the model as much as possible. Hence, the search space of this method is much smaller than that of the classical method. In addition, the higher the noise level, the lower the number of synchronous activities. Figures 7 and 8 show that with the gradual increase of the noise level, the scale of the two models is gradually close. However, the higher the noise ratio is, the closer the trace is to the real noise, the lower the significance of the analysis is, and the more it should be abandoned.

Table 4: The relationship between transitions and activities of trace σ.

Transition	Label	Activity
t_2	e	Exclusion of COVID-19 infection
t_8	c	CCU thrombolysis
	t	Transfer to isolation ward
t_{11}	r	Recanalization of thrombolysis in emergency patients

In the part of computing the optimal alignment, both methods use A $*$ search algorithm. The time complexity of A $*$ search algorithm in Algorithm 3 is $O\ (n^2 \log_2{}^n)$, and n is affected by the quantity of reachable markings. Even if the difference of the scale between the two models is not large, there will still be a large efficiency gap in the two methods. Figures 7–10 show that the quantity of transitions and arcs decreases less than 30%, and the mean queued nodes reduces by about 34%, and the mean computation time of optimal alignment reduces by about 40%.

According to the data and analysis in the experiments, when calculating the optimal alignment, since the efficiency of the optimal alignment increases geometrically with the model complexity, the selection of synchronous composition model can greatly improve the alignment efficiency.

4.4. Algorithm Effectiveness Verification. After the computation of the optimal alignment is completed, the optimal alignment results such as formula (2) are obtained. It can be clearly seen from the equation whether the activities of the patient's diagnosis and treatment process are normal and whether there are missing or multiple activities. Therefore, the medical staff can master the whole clinical pathway diagnosis and treatment process. An example in the diagnosis and treatment log is illustrated below.

Trace σ_2 = <. . ., exclusion of COVID-19 infection, . . ., CCU thrombolysis, transfer to isolation ward, recanalization of thrombolysis in emergency patients, . . .>, , and here, part of synchronous transitions are replaced by ellipses. The relationship between the activities and the transitions is shown in Table 4.

Trace σ_2 is denoted as <. . ., e, . . ., c, t, r, . . .> according to Table 4, and the optimal alignment result is shown in the following:

$$\gamma_2 = \left|\begin{array}{c|c|c|c|c|c|c} \ldots & e & \ldots & c & t & r & \ldots \\ \ldots & e & \ldots & c & \gg & r & \ldots \\ & t_2 & & t_8 & & t_{11} & \end{array}\right| \quad (3) \qquad (3)$$

According to the optimal alignment result of formula (3), it can be seen that the patient was excluded from COVID-19 infection at the beginning, but later transferred to the isolation ward which may be caused by many reasons. For example, as the epidemic situation intensifies, it is necessary to strengthen the protective measures for high-risk patients; or the patient contacted outside visitors with risk of infection during treatment, or the patient has concealed the travel information before admission to the hospital. The specific situation needs to be analyzed by the medical staff with the actual situation, which cannot be judged only from the logs.

The classical algorithm has been widely recognized and used for a long time, and its effectiveness is beyond reasonable doubt. Hence, the optimal alignments computed by the two algorithms need to be compared one by one. If all the results are the same, Algorithm 3 can be considered to be effective. Otherwise, if the results are different, it is possible that this algorithm be considered to be invalid.

Since the optimal alignment result is a sequence composed of nodes in the form of $(\alpha_2\ (t_x'), (\alpha_1\ (t_y), t_y))$, where t_x' corresponds to log model transition, $\alpha_2\ (t_x')$ is the activity corresponding to t_x', t_y corresponds to process model transition, and $\alpha_1\ (t_y)$ is the activity corresponding to t_y. Hence, after the optimal alignment is completed, the optimal alignment results obtained by the two algorithms are compared one by one to check whether the activity of the log model and the activity and the transition of the process model are exactly the same. According to the comparison results, it shows that all the optimal alignments are the same, which can illustrate that the algorithm is effective in deviation detection.

5. Conclusions

The deviation detection of clinical pathway is an important technology to standardize and study the diagnosis and treatment process and optimize the clinical pathway. The classical algorithm presented by Adriansyah et al. can synthesize the trace and process model and has a wide range of applications. Compared with the previous forward-looking methods, it has made a qualitative leap. However, with high complexity of search space, the efficiency in computing the optimal alignment is still unsatisfactory. Hence, this paper presents an optimization algorithm.

In this paper, the diagnosis and treatment log is preprocessed by the particularity of the diagnosis and treatment process. Considering that the alignment is logical based on the reachable graph to find the shortest path, even if the unnecessary transitions are only slightly reduced, the alignment efficiency can still be greatly improved. Hence, this paper uses the synchronous composition model for alignment computation, which greatly reduces the alignment time.

Finally, the clinical pathway of STEMI under COVID-19 is taken as an example for experimental analysis. It is illustrated that the newly proposed deviation detection method has the advantages of higher efficiency compared with the traditional algorithm, which can greatly shorten the time consumed in the deviation detection process. In the future work, this method can be applied to online deviation detection. Online deviation detection can timely detect the anomaly and remind patients of the deviation existing in the current completed diagnosis and treatment process. Meanwhile, it can predict the possible subsequent deviation and provide judgment basis for medical staff to carry out manual intervention to avoid adverse events. Online deviation detection requires higher efficiency, which can better reflect the advantage of the new method.

Data Availability

The data used to support the findings of this study are openly available at https://drive.google.com/file/d/1gkPRQXDNBzcAkoIcLdFLGMOGKluPhVdf/view?usp=sharing.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Research on the Evolution Path of China's Provincial Innovation Chain Model Based on Complex Network Model

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By constructing a complex network analysis model, this paper analyzes the data of 31 selected provinces in China from 2010 to 2019, summarizes China's provincial innovation chain development model, and then combined with the time series analyzes the evolution path of the model. The research shows that there is certain group proximity in China's provincial innovation chain in each year, and there are eleven models in ten years. The evolution path of the provincial innovation chain development model is mainly manifested in the development trend of low-level to medium-level and then high-level equilibrium model. Increasing investment and improving efficiency are the leading driving force for the development of China's provincial innovation chain. The medium-level equilibrium model runs through almost all years. Taking this as the node, the innovation driving force gradually changes from high investment to high efficiency.

1. Introduction

Discussing the mode and evolution of regional innovation chain is helpful to analyze the development direction of regional innovation chain and effectively optimize it and then has important theoretical and practical significance for the choice of the road of regional economic development. At present, the existing research on regional innovation mainly focuses on regional innovation system or regional innovation ecology. For the analysis of regional innovation development and its type differentiation, it has formed a variety of perspectives, such as efficiency perspective [1], system perspective [2], ecological perspective [3], and the perspective of regional innovation capability [4].

In terms of mode division and its development direction, it distinguishes China's high and low innovation capability aggregation areas from the perspective of innovation capability [5]. Several regional innovation models based on the manufacturing industry are compared and analyzed, and it is proposed that the Suzhou model is a better development direction [6]. Some researchers believe that different policies need to be formulated for different models to enhance their independent innovation ability [7]. Based on the analysis of innovation capability, it is found that the development shows the characteristics of agglomeration, especially in the eastern region (Wei Shouhua, 2021). Based on the comparative analysis of China's regional innovation models, it is proposed that the development direction should be the combination of technological innovation and non-technological innovation [8]. Some believe that regional innovation oriented to regional sustainable development should be established [9]. Based on the analysis of the distinctive regional innovation models of Jiangsu, Zhejiang, and Shanghai, it puts forward two basic construction ways, namely, the primary nature of market orientation and the late nature of government orientation [10].

In terms of research methods, in addition to some qualitative analysis combined with the original index data (such as [6]), quantitative analysis methods mainly focus on cluster analysis, such as Wu Yilin et al. [11]. Other quantitative methods, such as using factor analysis to measure the coupling degree of regional innovation [12], using Searle index and regional Gini index to discuss the spatial distribution and change trend of regional innovation capability [13], and using Moran analysis and spatial econometric model to analyze China's regional innovation capability [14], the application efficiency analysis distinguishes the differences and reasons of regional innovation [4].

In general, the existing studies, based on the distinction of types, do not fully discuss the development direction of its development model from the perspective of innovation chain, especially the development context and evolution path between models. In terms of methods, the existing common methods, such as factor and cluster analysis, can better distinguish various patterns, but they cannot analyze the internal similarity and external discrimination of types better, and their visual display is not explicit enough. The complex network modeling and analysis method can analyze the network relationship between objects by constructing point-to-edge mode and can deeply analyze the internal and external differentiation of patterns on the basis of pattern differentiation.

Therefore, based on the similarity perspective, this paper first comprehensively considers the regional innovation chain from the four dimensions of foundation, input, output, and achievement diffusion and constructs a comprehensive complex network model of 31 provinces and regions in mainland China from 2010 to 2019. Then, through community analysis, it divides subgroups, analyzes the characteristics of community agglomeration, and defines the model type of provincial innovation chain development. Then, combined with the time series, the evolution path of the model is found by analyzing the change of the type proportion of the provincial innovation chain development model in the time series.

2. Data and Methods

2.1. Regional Innovation Chain Index System. The relevant indicator systems of regional innovation are representatives, such as the "science, technology, and industry scorecard" of OECD, the national innovation capability index of the United States, and the Innovation Scoreboard of the European Union [15]. In addition, relevant studies have built an urban innovation support and input-output index system based on the theory of innovation vitality [16], emphasizing the importance of non-*R&D* indicators [17]. China's typical example is the report on China's regional innovation capability, which constructs an index system in five aspects: innovation environment, knowledge creation, knowledge acquisition, enterprise innovation capability, and economic benefits of innovation [18].

Based on the existing regional innovation evaluation index system, this paper constructs it from the perspective of innovation chain. In terms of index dimension, two dimensions of the main part of the regional innovation chain, innovation input (direct input of resources related to innovation) and innovation output (direct result output of innovation), as well as the postchain result part, innovation result diffusion dimension (transformation effect of innovation direct result), and the front chain foundation part, innovation foundation dimension, are considered. Therefore, the index system covers four links of the regional innovation chain: foundation, input, output, and application of achievements. In the selection of specific indicators, considering the respective contributions or influence of different innovation subjects (government, enterprises, scientific research institutions, and universities) in the innovation chain and drawing on the relevant rules of the EU Innovation Scoreboard, an index system including four dimensions, 12 primary indicators, and 24 specific indicators is constructed. For the selection of primary indicators, the regional innovation foundation includes the human and economic foundation, innovation service foundation, and innovation infrastructure, the regional innovation input includes the input of different innovation subjects (government, enterprises, scientific research institutions, and universities), and the regional innovation output includes the output of different innovation subjects (enterprises, scientific research institutions, and universities). The diffusion of regional innovation achievements includes the diffusion of innovation achievements of above designated enterprises and high-tech enterprises. In addition, this paper mainly considers the similarity between provinces, so the specific index data is mainly relative indicators. See Table 1 for details.

2.2. Data. This paper mainly uses the data from 2010 to 2019 from China Statistical Yearbook, China regional innovation capability report, China Science and technology statistical yearbook, and some local statistical yearbooks to collect and sort out the indicators of 31 provinces in China except Hong Kong, Macao, and Taiwan. Considering the data collection, this paper investigates the provincial innovation with enterprises above designated size instead of enterprises in the innovation subject. Since 2011, the statistical scope of industrial enterprises above designated size has been adjusted from French labor enterprises with an annual main business income of 5 million yuan and above to legal person industrial enterprises with an annual main business income of 20 million yuan and above.

2.3. Model Construction. This paper analyzes the complex network by constructing the complex network model. The complex network mainly analyzes the relationship between objects. This paper takes each province as a network node to form a complex network. By processing the index data, the cosine distance of each included angle is obtained, and the overall complex network diagram of 31 provinces is obtained by using UCINET(v6.5) software. Then, the complex network analysis method is used to analyze the community.

2.3.1. Distance Analysis between Provinces. Specifically, directed weightless network, directed weightless network, directed weightless network, and undirected weightless network belong to complex networks. At the same time, the setting of the relationship between network nodes affects the key core of the network. The interprovincial association complex network constructed in this paper is based on

Table 1: Construction of regional innovation chain index system.

Dimension	Primary index	Specific indicators
Regional innovation foundation	Humanistic economic foundation	Per capita GDP (yuan/person)
		Years of education per capita (years/person)
		Consumption level of residents (yuan/person)
	Innovation service foundation	Per capita technology market transaction amount (by flow direction) (yuan/person)
		Number of scientific research institutions per capita (10000 persons)
		Average amount of loans from financial institutions for scientific research expenditure of large and medium-sized industrial enterprises (10000 yuan/piece)
	Innovation infrastructure	Per capita road ownership (km/person)
		Average number of mobile phones per 100 households of households in various regions (department/100 households)
Regional innovation investment	Government investment	Proportion of government *R&D* expenditure in local GDP (%)
	Investment of enterprises above designated size	Proportion of *R&D* personnel of enterprises above designated size in employees of enterprises above designated size (%)
		Proportion of *R&D* expenditure of enterprises above designated size in local GDP (%)
		Proportion of total expenditure of technology purchase, introduction, absorption, and transformation of above designated enterprises in regional GDP (%)
	R&*D* organization investment	Proportion of *R&D* personnel in *R&D* institutions in each region (%)
		Proportion of *R&D* expenditure of *R&D* institutions in regional GDP (%)
	Investment in colleges and universities	Proportion of *R&D* personnel in colleges and universities in each region (%)
		Proportion of *R&D* funds of colleges and universities in regional GDP (%)
Regional innovation output	Output of enterprises above designated size	Average number of patent applications of industrial enterprises above designated size in each region (pieces/10000 people)
	Output of scientific research institutions	10000 people have an average of scientific and technological papers published by *R&D* institutions in various regions (articles/10000 people)
		Average number of patent applications of *R&D* institutions in various regions owned by 10000 people (pieces/10000 people)
	Output of colleges and universities	10000 people have an average of scientific and technological papers published by colleges and universities in various regions (articles/10000 people)
		Average number of patent applications of colleges and universities in various regions owned by 10000 people (pieces/10000 people)
Diffusion of regional innovation achievements	Diffusion of innovation achievements of enterprises above designated size	Proportion of new product output value of enterprises above designated size in total industrial output value (%)
	Diffusion of innovation achievements of high-tech enterprises	Proportion of output value of new products of high-tech industry in total output value (%)
		Proportion of new product export revenue of high-tech industry in new product sales revenue (%)

similarity distance and belongs to an undirected weighted network.

To build a complex network model, we must first standardize the index data used. In this process, the final 24 specific indicators are considered because they reflect the corresponding primary indicators and corresponding dimensions. And further, determine the relationship between provinces.

Let the index data of each province be $Y_{ij} = \left\{Y_{ij}, i = 1, 2 \ldots; j = 1, 2 \ldots\right\}$, y_{ij} represents the score of the *i*th province in the *j*th index, *i* Max 30, and *j* Max 24. For comparability, the original scores of all provinces under each indicator are divided by the square root of all original scores of the indicator as the standard score. The standard score matrix is

$$X_{ij} = \frac{Y_{ij}}{\sqrt{1/I \sum_{k-1}^{K} Y_{kj}^2}}. \tag{1}$$

$X_{ij} = \left\{X_{ij}, i = 1, 2 \ldots; j = 1, 2 \ldots\right\}$.

There are many ways to define the distance between provinces, which can reflect many differences between provinces. The included angle cosine distance between provinces R and S can be defined as

$$P_{rs} = 1 - \frac{\sum_{j-1}^{J} X_{rj} X_{zj}}{\sqrt{\sum_{j-1}^{J} X_{rj}^{2}} \sqrt{\sum_{j-1}^{J} X_{sj}^{2}}}. \quad (2)$$

The distance between R and S provinces is the cosine of the included angle of the vector composed of 24 indexes. All are nonnegative indicators, so [0, 1] is the value range of included angle cosine distance. The similarity of characteristics between provinces or the similarity of the development model can be expressed by this distance. Some provinces are economically developed, but the cosine distance between them and provinces with the same economic level is very large; the reason is that the two provinces have a different bias on a specific index, so the similarity between them is not high. This formula focuses more on similarity and difference in the analysis of provinces.

After setting the relationship between provinces, it is necessary to further set the edges in the complex network, that is, the connection relationship between nodes. Taking each province as the node and the relationship between provinces as the edge, a complex network of provincial innovation chain relationship can be established. For the distance matrix, there are two kinds of methods to establish edges. One is the threshold method; that is, according to the invariant topological properties [19], network connectivity [20], and the minimum spanning tree and event union (Wang *J*, Yang *h*, 2009) criteria, set a threshold, and the establishment of edges is set between node pairs whose distance is less than or equal to the threshold. The second type is the maximum edge restriction method; that is, specify a value to establish the maximum upper limit of each node connected to several nearest nodes [21]. This paper adopts the former method, that is, threshold method, and selects the maximum value of the minimum distance between each province and other provinces in the provincial distance matrix as the standard value. If it is less than or equal to this value, it will judge the similarity between the corresponding two provinces as the position and strength of each province in the whole provincial innovation network. Therefore, a complex network model of the provincial innovation chain is constructed.

2.3.2. Division and Analysis of Complex Network Communities in Provincial Innovation Chain. According to Newman's research on community structure, in the complex network of the provincial innovation chain, the provinces with a high degree of similarity include angle cosine distance from each community (subgroup). Therefore, the provinces are classified according to the community. On the basis of calculating the cosine distance of the included angle between provinces and determining the value of the distance matrix, the distance matrix is binarized. So the undirected binary relationship network diagram can be formed by the provincial innovation chain network, and then the community analysis of the provincial innovation chain can use the factional division method.

As for the division of communities, there are two methods: cliques and faces. According to the observation results of the complex network graph, it is forcibly divided into several most suitable groups (3–8 groups), so it is divided into various subgroups.

The extended subgroup density relation matrix can be obtained from the analysis of the combined block model [22]. The matrix describes the density relationship between the subgroup itself and the subgroup so that the similarity analysis between and within the subgroup can be carried out. It is also used to detect whether the above grouping is most appropriate.

This paper comprehensively analyzes the community division of provinces from four dimensions in order to find out the similarity of the innovation chain model among provinces. Combined with the time series, the development mode and path of the province are analyzed.

2.3.3. An empirical Analysis of China's Provincial Innovation Chain Model and Its Evolution Path. Based on the construction and analysis of the provincial innovation chain complex network model, combined with the data of 24 indicators in 31 provinces from 2010 to 2019, this paper uses UCINET (v6.5) software to analyze the provincial innovation chain complex network.

For the results processed by UCINET (v6.5) software community, we need to further combine the data analysis and then summarize the characteristics of each subgroup to obtain the innovation chain model of different years and provinces in China. Finally, through the comparison of time dimensions, this paper summarizes and refines the evolution path of the provincial innovation chain model.

2.4. Model Differentiation and Analysis of China's Provincial Regional Innovation Chain from 2010 to 2019. After the complex network analysis of the data, the complex network diagram is shown in Figure 1 (space limitation, only four annual graphs are shown).

Further, combined with the observation of the complex network diagram of each year, each year is divided into 4–5 subgroups by the mandatory method, and the similarity between subgroups and the appropriateness of grouping are analyzed by expanding the subgroup density relationship matrix. The division of complex network subgroups of provincial innovation chain in each year is shown in Table 2.

Analyze the original data of the relevant indicators of the four modules of each subgroup of the province in each year, and divide the data into five levels: poor, lower middle, middle level, upper middle, and better. Then, combined with the expert analysis method, 11 models are defined for all years. The first appearance and brief analysis of various models are as follows: in 2010, the first subgroup of provinces had poor innovation foundation, low innovation input, low innovation output, and less diffusion of innovation achievements. We defined it as the leading model of low input and low output. The provinces of the second subgroup have weak innovation foundation, medium innovation input, medium innovation output, and diffusion of innovation

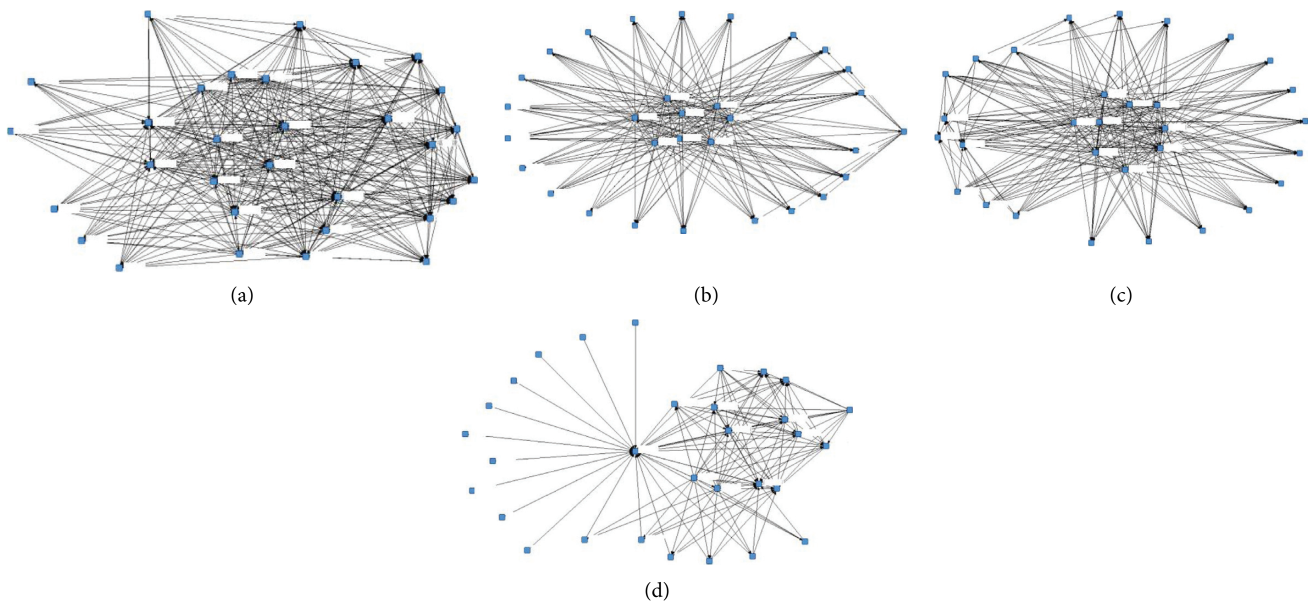

Figure 1: Annual complex network diagram of China's provincial innovation chain: (a) 2010 network diagram; (b) 2013 network diagram; (c) 2016 network diagram; (d) 2019 network diagram.

Table 2: Division of complex network subgroups of provincial innovation chain in each year.

Year	Subgroup	Province	Pattern
2010	First subgroup	Tibet and Qinghai	Leading mode of low input and low output
	Second subgroup	Heilongjiang, Guizhou, Inner Mongolia, and Shaanxi	CIC's weak equilibrium model
	Third subgroup	Beijing, Tianjin, Shanghai, Shandong, Fujian, Zhejiang, and Jiangsu	Higher-level equilibrium model
	Fourth subgroup	Hebei, Shanxi, Jilin, Anhui, Jiangxi, Henan, Liaoning, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Yunnan, Gansu, Ningxia, and Xinjiang	Low-level equilibrium model
2011	First subgroup	Xinjiang, Gansu, and Ningxia	Low-level equilibrium model
	Second subgroup	Hebei, Yunnan, Heilongjiang, Jiangxi, Sichuan, Guizhou, Tibet, Inner Mongolia, Jilin, Anhui, and Henan	CIC's weak equilibrium model
	Third subgroup	Beijing, Shanghai, Zhejiang, and Guangdong	Higher-level equilibrium model
	Fourth subgroup	Shanxi, Fujian, Shandong, Hubei, Hunan, Hainan, Shaanxi, Qinghai, Tianjin, Liaoning, Guangxi, Chongqing, and Jiangsu	Medium-level equilibrium model
2012	First subgroup	Sichuan, Yunnan, Tibet, Ningxia, Xinjiang, and Qinghai	High input and high diffusion mode
	Second subgroup	Shanxi, Inner Mongolia, Heilongjiang, Jiangsu, Shandong, Henan, Guizhou, Anhui, Hunan, Guangxi, and Chongqing	Medium-level equilibrium model
	Third subgroup	Beijing, Tianjin, Shanghai, Zhejiang, Fujian, Guangdong, Jiangxi, and Shaanxi	High-level equilibrium model
	Fourth subgroup	Hebei, Liaoning, Jilin, Hubei, Hainan, and Gansu	CIC's weak equilibrium model
2013	First subgroup	Hubei, Hainan, Chongqing, Sichuan, Tibet, Shaanxi, Qinghai, Ningxia, and Xinjiang	Leading mode of high investment and high diffusion
	Second subgroup	Hebei, Liaoning, Anhui, Jiangxi, Henan, Guangdong, and Gansu	Low-level equilibrium model
	Third subgroup	Beijing, Jilin, Heilongjiang, Shanghai, Zhejiang, and Fujian	Higher-level equilibrium model
	Fourth subgroup	Tianjin, Shanxi, Inner Mongolia, Jiangsu, Shandong, Hunan, Guizhou, Guangxi, and Yunnan	Medium-level equilibrium model
2014	First subgroup	Hebei, Jiangsu, Anhui, Shandong, Guangxi, Sichuan, Yunnan, Tibet, Gansu, and Xinjiang	Medium-level equilibrium model

Table 2: Continued.

Year	Subgroup	Province	Pattern
	Second subgroup	Shanxi, Liaoning, Jilin, Hubei, Hainan, Guizhou, Shaanxi, and Qinghai	Medium base weak equilibrium model
	Third subgroup	Beijing, Tianjin, Inner Mongolia, Shanghai, Hunan, Guangdong, and Chongqing	High-efficiency output leading mode
	Fourth subgroup	Heilongjiang, Zhejiang, Fujian, Jiangxi, Henan, and Ningxia	Equilibrium model in weak input
2015	First subgroup	Shanxi, Liaoning, Shanghai, Henan, Hunan, Guangxi, Xinjiang, Tibet, Gansu, and Ningxia	Medium-level equilibrium model
	Second subgroup	Jilin, Heilongjiang, Zhejiang, Anhui, Guizhou, Shaanxi, and Qinghai	CIC's weak equilibrium model
	Third subgroup	Beijing, Hebei, Jiangsu, Jiangxi, Shandong, Guangdong, and Chongqing	Higher-level equilibrium model
	Fourth subgroup	Tianjin, Inner Mongolia, Fujian, Hubei, Hainan, Sichuan, and Yunnan	Medium base weak equilibrium model
2016	First subgroup	Hebei, Jiangsu, Shandong, Guangxi, Yunnan, Tibet, and Xinjiang	Equilibrium model in weak input
	Second subgroup	Heilongjiang, Zhejiang, Fujian, Shaanxi, Qinghai, and Ningxia	Medium-level equilibrium model
	Third subgroup	Beijing, Tianjin, Inner Mongolia, Shanghai, Anhui, Hunan, Guangdong, Chongqing, and Gansu	High-efficiency output leading mode
	Fourth subgroup	Shanxi, Liaoning, Jilin, Jiangxi, Henan, Hubei, Hainan, Sichuan, and Guizhou	Medium base weak equilibrium model
2017	First subgroup	Heilongjiang, Fujian, Henan, Hubei, Hainan, and Guizhou	Equilibrium model in weak input
	Second subgroup	Zhejiang, Hunan, Chongqing, and Ningxia	Medium investment and high diffusion dominated model
	Third subgroup	Hebei, Jilin, Anhui, Shandong, Yunnan, and Xinjiang	Medium-level equilibrium model
	Fourth subgroup	Beijing, Tianjin, Inner Mongolia, Jiangsu, Jiangxi, Guangdong, Guangxi, Sichuan, Tibet, and Gansu	High-efficiency output leading mode
	Fifth subgroup	Shanxi, Liaoning, Shanghai, Shaanxi, and Qinghai	Leading mode of high foundation and high yield
2018	First subgroup	Tianjin, Inner Mongolia, Jiangxi, Hunan, Sichuan, Tibet, and Gansu	Equilibrium model in weak input
	Second subgroup	Hebei, Shanxi, Ningxia, Shandong, Guizhou, Yunnan, Shaanxi, Qinghai, and Xinjiang	Medium base weak equilibrium model
	Third subgroup	Jiangsu, Anhui, Hainan, and Chongqing	Leading mode of high foundation and high yield
	Fourth subgroup	Heilongjiang, Henan, Hubei, and Guangxi	Medium-level equilibrium model
	Fifth subgroup	Beijing, Liaoning, Jilin, Shanghai, Fujian, Zhejiang, and Guangdong	Higher-level equilibrium model
2019	First subgroup	Beijing, Guangdong, Zhejiang, Jilin, Shanghai, Jiangsu, Fujian, and Shandong	Higher-level equilibrium model
	Second subgroup	Tianjin, Inner Mongolia, Anhui, Jiangxi, Hebei, Guangxi, Sichuan, Tibet, and Gansu	Equilibrium model in weak input
	Third subgroup	Shanxi, Liaoning, Hunan, Chongqing, Shaanxi, Qinghai, Guizhou, and Yunnan	Medium-level equilibrium model
	Fourth subgroup	Heilongjiang, Henan, Hubei, Hainan, Ningxia, and Xinjiang	Medium investment and high diffusion leading model

achievements. We define it as the medium input weak equilibrium model. The third subgroup has a good innovation foundation, high innovation input, high innovation output, and good diffusion of innovation achievements. We define it as the high-level equilibrium model. The provincial innovation foundation, innovation input, innovation output, and innovation achievement diffusion of the fourth subgroup are in the lower middle position, which we define as the low-level equilibrium model. In 2011, the provincial innovation base and innovation output of the fourth subgroup were in the lower middle position, and the innovation input and innovation achievement diffusion were in the middle level. We define it as the medium-level equilibrium model. In 2012, the provincial innovation base and innovation output of the first subgroup were in the lower middle position, and the diffusion of innovation input and innovation achievements was good. We defined it as the high input and high diffusion model. In 2014, the provincial

Table 3: Summary of annual provincial innovation chain development model.

Year	Subgroup pattern and proportion										
	Leading mode of low input and low output (%)	Low-level equilibrium model (%)	CIC's weak equilibrium dominant model (%)	Medium base weak equilibrium model (%)	Medium-level equilibrium model (%)	Equilibrium model in weak input (%)	Leading mode of high investment and high diffusion (%)	Leading mode of high foundation and high output (%)	Medium investment and high diffusion leading model (%)	Higher-level equilibrium model (%)	High-level equilibrium model and high-efficiency output leading model (%)
2010	6.50	57.90	12.90							22.60	
2011		9.70	35.40		41.90					12.90	
2012			19.40		35.50		19.40			25.80	
2013		22.60			29.00		29.00			19.40	
2014				25.80	32.30	19.40					22.60
2015			22.60	22.60	32.30					22.60	
2016				29.00	19.40	22.60					29.00
2017					19.40	19.40		16.10	12.90		32.30
2018				29.00	12.90	22.60		12.90		22.60	
2019					25.80	29.00			19.40	25.80	

innovation base of the second subgroup was at the middle level, and the innovation input, innovation output, and innovation achievement diffusion were at the lower middle level. We defined it as the medium base weak equilibrium model. The innovation base, innovation output, and innovation achievement diffusion of the third subgroup are in the upper middle position, but the innovation output is very considerable, which we define as the leading mode of high-efficiency output. The provinces of the fourth subgroup belong to the innovation foundation, and innovation output and innovation achievements are at the middle level, but the innovation input is at the lower middle position. We define it as the medium equilibrium model of weak input. In 2017, the provincial innovation base and innovation output of the second subgroup were in the lower middle position, the innovation input was in the middle level, and the diffusion of innovation achievements was high, belonging to the dominant mode of medium input and high diffusion. The provinces of the fifth subgroup have a good innovation foundation, the diffusion of innovation input and innovation achievements is at a medium level, and the innovation output is high. We define it as the leading model of high foundation and high output.

2.5. Analysis of the Evolution Path of China's Provincial Innovation Chain Development Model. Further, we analyze the evolution path of China's provincial innovation chain development model and compare the number of provinces in each subgroup with the number of provinces in China to calculate the proportion of each model, so the provinces in China can be summarized as shown in Table 3.

Generally speaking, the main mode of China's provincial innovation chain is around innovation input and innovation output. From 2012, it began to pay attention to the innovation foundation and the diffusion of innovation achievements. In 2014, a high-level balanced development mode began to appear, slowly approaching the high-efficiency development mode. This shows that the development of China's provincial innovation chain is based on innovation input, pays more attention to innovation input and innovation output, and weakens the innovation foundation and the diffusion of innovation achievements. With the development of China's economy, the development of the two dimensions of input and output has affected or spread to other dimensions, showing a four-dimensional synchronous development trend, and began to pay attention to efficiency development and improve the quality of innovation.

At the same time, the annual scores and proportion of the eleven models in all years are quite different, and there are some main models, transition models, and edge models. From the overall trend of the development model of regional innovation chain from 2010 to 2019, the evolution of its main model is from low-level equilibrium model to medium-level equilibrium model and then to high-level equilibrium development. The medium-level equilibrium model runs through almost all years, taking this as the node innovation driving force, and gradually changes from high investment to high efficiency. In this trend, there are corresponding transition modes between the two stages of balanced development mode transformation, which are mainly started and driven by increasing investment or improving efficiency, such as medium input weak equilibrium mode, weak input medium equilibrium mode, and medium input high diffusion dominant mode. Therefore, it can be seen that the leading evolution path of the provincial innovation chain development model is to start with the low-level equilibrium model and develop from the medium-level equilibrium to the high-level equilibrium model. The auxiliary evolution path is investment enhancement path and efficiency improvement path.

3. Research Conclusion

Using the complex network model and the regional innovation-related data of 31 provinces in mainland China in recent ten years, this paper analyzes the four modules of China's innovation foundation, innovation input, innovation output, and innovation achievement diffusion, so as to investigate the development mode and evolution path of provincial innovation chain in China. The research findings are as follows: (1) Each year, the regional innovation chains of 31 provinces in China show certain group proximity. Each year, all provinces in China can be divided into 4 or 5 modes, and a total of 11 modes are shown in all years: low input and low output leading mode, low-level equilibrium mode, medium input weak equilibrium leading mode, medium foundation weak equilibrium mode, medium-level equilibrium mode, weak input medium equilibrium model, high input high diffusion leading model, high foundation high output leading model, medium input high diffusion leading model, high-level equilibrium model, and high-efficiency output leading model. (2) From 2010 to 2019, China's provincial innovation chain development model developed along the low-level-medium-level-high-level equilibrium model on the main model evolution path. The model evolution was mainly started and driven by increasing investment or improving efficiency. There were corresponding transition models between the two stages of balanced development model transformation, such as medium input weak equilibrium model, weak input medium equilibrium model, and medium input high diffusion dominant model. (3) The development model of China's provincial innovation chain shows a good trend: starting from innovation input, focusing on innovation input and innovation output, and then affecting or spreading to other dimensions, showing a four-dimensional synchronous development trend. However, the medium-level equilibrium model runs through almost all years. Taking this as the node, the innovation driving force gradually changes from high investment to high efficiency.

The enlightenment is as follows: for China as a whole, under the overall trend of the evolution path of China's provincial innovation chain development model, it is necessary to pay attention to the shortcomings of the simple promotion mode of high investment advocated all the time and turn to the high-efficiency promotion of quality and high yield and high diffusion of connotation, in order to more reasonably and effectively improve the development level of provincial innovation chain. In addition, for each province, it is necessary to correctly understand the development status of the innovation chain of the province and the previous evolution path and design the promotion ways and paths more in line with its own reality and historical situation.

Data Availability

The dataset used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

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Research Article

Evaluation of Rural Tourism Spatial Pattern Based on Multifactor-Weighted Neural Network Algorithm Model in Big Data Era

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In recent years, due to the rapid development of rural tourism, rural tourism has lost its unique rurality, which has led to a certain impact on the sustainable development of rural tourism. Primarily, based on the rural characteristics, the social environment development, population development, and economic development are taken as the research indexes, and the evaluation index system of rural tourism destination is constructed. Afterward, an empirical study on the spatial pattern of rural tourism is carried out with examples, and the model is simulated and analyzed by MATLAB software. Finally, the spatial autocorrelation method is used to analyze the evolution characteristics of the rural tourism spatial pattern. The results show that through the analysis of the evaluation error curve of the Back Propagation Neural Network (BPNN), the evaluation error and the actual error range are within 0.08%, which proves that the BPNN algorithm has good calculation accuracy. The BPNN rural tourism destination rurality evaluation model established here can make an effective evaluation of rural tourism space. The results show that the proportion of employees in the primary industry and the penetration rate of mobile phones are the decisive factors in the adjustment of industrial structure and social environmental factors, respectively. Rural per capita tourism income and the proportion of primary industry output value will also have a certain impact on rural evolution. Certain guiding significance is provided for the sustainable development of rural tourism.

1. Introduction

With the rapid development of information technology and Internet technology, the importance of big data technology is increasingly focused by various industries. Big data refer to massive and complex data that cannot be processed by traditional data processing methods. Both accurate analyzation of consumers' consumption behavior and decision-making can be realized through big data technology so that various business activities can be carried out in a targeted manner. With the rapid development of China's urbanization process, people's demand for rural and urban tourism is getting higher and higher. Meanwhile, China's rural tourism has developed very well in recent years [1]. However, problems in rural tourism have occurred during the rapid development of rural tourism, among which the most important one is the marketization of tourism destinations, which leads to the gradual weakening of the rural nature of rural tourism destinations and conflicts with the sustainable development of rural tourism.

Due to the rapid advancement and development of urbanization, the population flow between cities and villages has become increasingly frequent, thus strengthening the interaction of economic and social development factors cities and villages. The rural industrial structure and layout are constantly being adjusted. The fading of "homesickness" memory and rural spatial differentiation have made the rural research increasingly significant. Scholars from all walks of life have begun to pay attention to the study of rural nature [2]. At present, researchers all over the world have made a series of researches and discussions on the rural theory. Gao et al. [3] constructed the framework of rural spatial reconstruction driven by tourism. The changing process of rural spatial reconstruction was revealed by using geographic information system and participatory field investigation. The research showed that rural spatial reconstruction driven by tourism was the result of internal and external forces, while land consolidation was the direct way to trigger rural spatial reconstruction. Rural tourism can accelerate land consolidation and realize rural revitalization. Panzer-Krause et al. [4] conducted a standardized survey on tourists in Giant Causeway, the most visited scenic spot in Northern Ireland. The results showed that the awareness of sustainability had declined from individual tourists to long-distance tourists and then to cruise tourists, so it is necessary to manage sustainability in specific market segments. Rural tourism hot spots should be the hub to coordinate and promote the network of regional tourism providers, so as to realize their real integration into rural communities. Verma et al. [5] used data from the land satellite to conduct a survey on rural areas in Varanasi County. Also, results showed that the agricultural area (accounting for 50% of the land cover area) increased by 37% and the building area increased by 236% during 1993–2013 in Varanasi County. A relative rural development index was developed to understand the comparative development of rural blocks in the region. Qi et al. (2021) [6] took 169 villages in Jingyuan County as the research object, and the evaluation index system of rural development level was constructed from the perspective of factor structure function. The rural development level and spatial structure characteristics of Jingyuan County were analyzed by rural development index, regional function index, nearest neighbor index, and exploratory spatial data analysis, and the types and specific paths of rural development are determined. The results showed that the rural development level of Jingyuan County was low, which can be described as "high developing level in south areas but low developing level in north areas." Yang et al. (2021) [7] used multisource data, such as remote sensing images, building data, official websites, and field surveys to investigate the morphology and social evolution of rural communities from the perspective of tourism, and analyzed its driving factors.

Rural settlements are places where ancestors lived, and some unique landscape elements become the foundation of rural nature [8]. However, due to the rapid development of urbanization and rural tourism, rural development is facing new problems and challenges. One of the most important problems is that the development of some rural areas is disorderly and spontaneous. Urban characteristics, landscape construction, and the phenomenon in the process of rural tourism marketization are on the rise. Consequently, the original rural settlement landscape has been greatly negatively affected [9,10]. The originally good natural ecological environment in rural areas has been destroyed, and the problems in rural economic structure, villagers' culture, and lifestyle have become increasingly prominent. As a kind of rural tourism, its most basic charms have been seriously ignored in rural areas, and its rural nature is gradually losing in rural tourism areas [9]. The sustainable development of rural tourism will face severe challenges, and it is urgent to pay attention to rural development from a deeper and wider

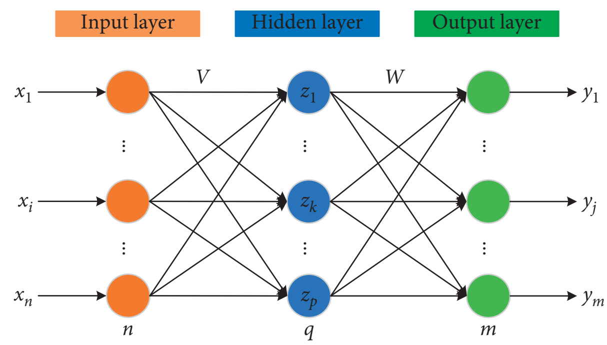

Figure 1: BPNN structure.

level. Tourism destinations must enhance their value cognition level and implement rural protection of tourism destinations. Therefore, the influencing factors of rural tourism destination are taken as the breakthrough point. An evaluation model of the rural tourism spatial pattern based on the neural network algorithm is implemented to evaluate the spatial pattern of rural tourism. Certain guiding significance is provided for the sustainable development of rural tourism.

2. Method

2.1. BP Neural Network. Back propagation neural network (BPNN) has become one of the most commonly used algorithms in the field of machine learning (ML) in recent years [11,12]. The artificial neural network (ANN) is composed of interconnected neurons. Also, each neuron receives the information sent by the neurons in the previous layer and transmits the received information through nonlinear transformation. The neural network can approach complex mapping relations through training and has wide applications in pattern recognition, function approximation, and classification prediction [13]. BPNN consists of three parts: input layer, hidden layer, and output layer. The hidden layer can have multiple layers, and each layer can contain different numbers of neurons [14]. When BPNN works, primarily, data samples are imported through the input layer. Then, through a series of mathematical calculations, the laws between the data are obtained. Finally, all prediction datasets are calculated by using these laws, and the prediction results are obtained. Figure 1 displays the structure of BPNN.

The specific expression of BP is as follows:

$$
\begin{aligned}
W_{R\times S} &= \begin{bmatrix} W_{0,0} & W_{0,1} & \cdots & W_{0,S-1} \\ W_{1,0} & W_{1,1} & \cdots & W_{1,S-1} \\ \vdots & \vdots & \vdots & \vdots \\ W_{R-1} & W_{R-1} & \cdots & W_{R-1,S-1} \end{bmatrix} \\
W_{S\times N} &= \begin{bmatrix} W_{0,0} & W_{0,1} & \cdots & W_{0,S-1} \\ W_{1,0} & W_{1,1} & \cdots & W_{1,S-1} \\ \vdots & \vdots & \vdots & \vdots \\ W_{R-1} & W_{R-1} & \cdots & W_{R-1,S-1} \end{bmatrix}.
\end{aligned} \tag{1}
$$

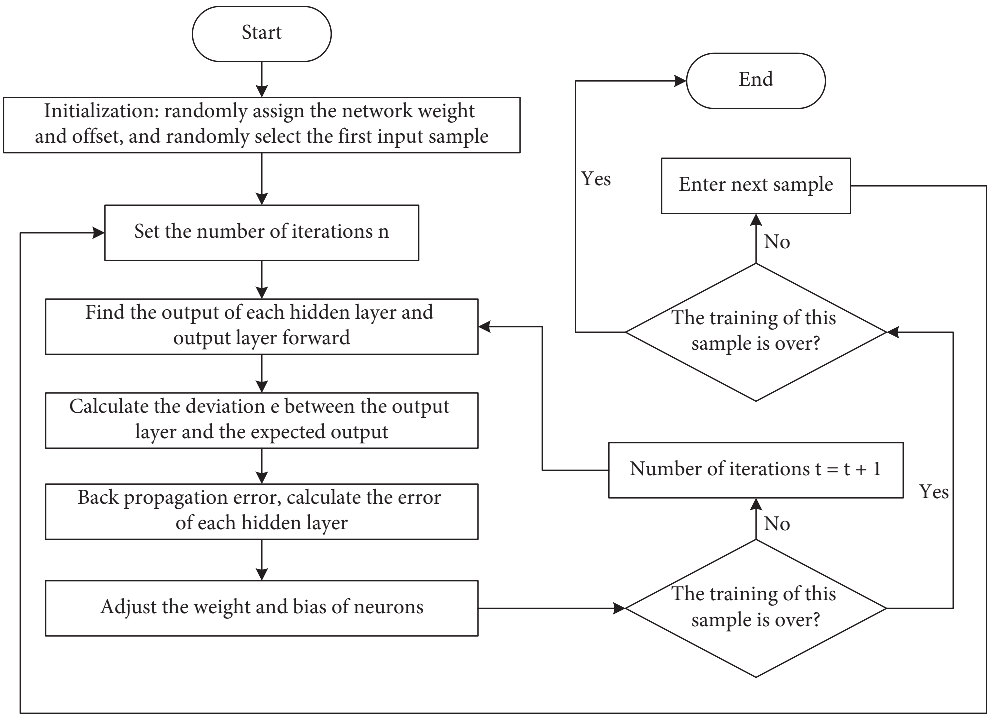

Figure 2: Algorithm flow of BPNN.

The matrices V and W are the connection weight matrices of the output layer and the hidden layer, and the connection weight matrices of the hidden layer and the input layer, respectively.

In the process of calculation, the data are propagated forward. In this process, the weights and deviations of hidden neurons are obtained randomly. The neural network is propagated forward to obtain the sum of each neuron, and the data on the neuron are transmitted to the next neuron through the activation function [15]. The neurons in the output layer also apply the activation function to complete the forward propagation of the neural network, and calculate the error between the output value and the actual output value of the output layer. The specific expression is as follows:

$$E = \frac{1}{2}(t - y)^2, \tag{2}$$

where E stands for the square of error, t refers to the expected value of the sample output, and y represents the actual output result.

Figure 2 signifies the algorithm flow of BPNN.

A “gradient descent method” is used to optimize the weights of neural networks, and the differential chain rule is mainly used to calculate the partial derivatives of error E relative to the weights of networks W_{ij} [16]. Utomo (2017) [17] proposed a gradient-based BPNN method to improve the optimization of stock price prediction. In the BPNN method, the gradient descent method is used to adaptively determine the learning rate, the training cycle, and other parameters, to obtain the best value in the stock data processing process, and to obtain the accuracy of the prediction during training. The calculation method is as follows:

$$\frac{\partial E}{\partial w_{ij}} = \frac{\partial E}{\partial o_j}\frac{\partial o_j}{\partial n\,et_j}\frac{\partial n\,et_j}{\partial w_{ij}}, \tag{3}$$

where j represents the neuron input and net_j refers to constraint neuron J. In the equation $o_j = y$, the derivative y is used to indicate the rate of change of the value, and the derivative or the slope is used to minimize the error. The partial derivative of the error term relative to the output of a specific neuron j is calculated as follows.

The method of expressing the neuron output partial derivative of the input neuron is as follows:

$$\frac{\partial o_j}{\partial n\,et_j} = \frac{\partial}{\partial n\,et_j}\varphi\left(net_j\right)\left(1 - \varphi\left(net_j\right)\right). \tag{4}$$

The partial derivative of the actual output value o_i is calculated as follows:

$$\frac{\partial n\,et_j}{\partial w_{ij}} = \frac{\partial}{\partial w_{ij}}\left(\sum_{k-1}^{n} w_{ij}o_k\right) = \frac{\partial}{\partial w_{ij}}w_{ij}o_k = o_i. \tag{5}$$

The weights of neurons in each layer of BPNN can be determined by a partial derivative and a learning rate. When using BPNN for calculation, it is necessary to repeat the above steps continuously until the error between the output value and the expected value reaches the allowable range or reaches the maximum times of iterations of NN. The advantage of using gradient descent method to improve BPNN is that the adjustment of weights and thresholds can further eliminate the instability in the neural network caused by the large variation of gradient value in the gradient adjustment process.

2.2. Study Area. Rural tourism refers to tourism activities that take nature, humanities, and cultures of villages as objects and attractions [18]. The meaning of rural tourism includes two features: the first feature is that the rural tourism destination is in the rural areas, and the second feature is the unique rural nature. These two points must be met in tourist activities at the same time to be called rural tourism [19,20]. Therefore, in the process of developing rural tourism, attention should be paid to the maintenance of rural images. Only by maintaining the original features of rural areas can urban people return to nature and the sustainable development of rural environment be ensured [21,22]. Rural nature is a restatement of the concept of rural regions. It is the harmony among human beings, architecture, and nature. It runs through rural history and is the result of harmonious coexistence between human beings and nature. Population characteristics and production scales are the basis of sustainable development and inheritance of human civilization.

Jiahu District of Hangzhou City in the north of Zhejiang Province is taken as the study area, which has been a land of fish and rice resources since ancient times, with flat terrain and beautiful scenery. The Zhejiang hinterland is a province with dense water resources, eutrophication of water bodies, and high degree of landscape ecology, which occupies a very important position in water resources and landscape ecosystem. A Hangzhou-Jiaxing-Huzhou region has a unique humanistic style and rich rural tourism resources, which provides conditions for the development of rural tourism. Based on local resources and existing farmers' production factors, a number of famous rural tourism brands have been created, which are identified as "Zhejiang Agricultural Villages" in small towns (villages) and "Hangjianghu agricultural areas." From the aspect of social and economic development, through the analysis of tourism resources, tourism level, geographical environment, and traffic location, results show that Jiahu District of Hangzhou is the largest rural tourism development zone in Zhejiang Province, with the highest management level and the largest scale. Zhejiang Province has become one of the first provinces to develop rural tourism in China. Taking the construction of beautiful villages as the carrier, it is one of the most abundant and mature areas of tourism resources in China. The Hangzhou-Jiaxing-Huzhou region gives a full play to the interactive role of new rural construction and rural tourism development. Through the development of rural tourism, the vast number of rural residents get employed, which strengthens the economic strength of rural areas and realizes the rapid development of rural economy. Significant changes have taken place in rural areas, and farmers' lives have also been greatly improved, which has become a classic example of urbanization of new rural cooperative economic organizations in China's ecological civilization construction. Therefore, it is a typical and representative problem to choose this area as the research object.

The data come from the statistical yearbooks of Hangzhou City, Zhejiang Province in 2010, 2015, and 2020, while other data are obtained through the compound calculation.

2.3. Construction of Rural Indicators of Rural Tourist Destinations Based on Neural Networks. The comprehensive description of rural development is the result of multifactors' integration, and the change of each factor determines the alternation of the direction of rural development. According to the research content on the concept and connotation of rurality in the rurality theory, rurality is the unique attribute of rural regions, including land use structure, industrial structure, infrastructure, and other factors. In addition, the current relevant research results usually display indicators from the population settlement, economic development, social development, land use, infrastructure, and other aspects, which are used to construct the rurality evaluation index system. Based on this, it is preliminarily proposed to construct the rurality evaluation index system of tourism destinations from the aspects of population development, economic level, social environment development, and infrastructure. Through the study of relevant literature, combined with the particularity of rural tourism destination, the representative, comparable, and easily accessible indicators are comprehensively selected. The four primary indicators of social environment development, economic level, population development, and infrastructure and the 15 secondary indicators after subdivision are taken as evaluation indicators. Figure 3 shows the rural evaluation index system.

2.4. Rural Tourism Evaluation Index Weight. The calculation method of rural index (RI) of rural tourist destination is a linear weighting method, and the method of determining index weight W_j is an entropy weight method. Because the dimensions of data are different, it will lead to inconvenient calculation. Therefore, the data should be standardized. The method used here is the range standardization, namely, using the maximum or minimum value according to the standard value of the index value. By calculating the difference between the current value and the maximum or minimum value of each index value, the ratio between each index value and each index value standardization is realized.

When parameter X_{ij} is a positive indicator,

$$A_{ij} = \frac{X_{ij} - \min\left(X_j\right)}{\max\left(X_j\right) - \min\left(X_j\right)}. \tag{6}$$

When parameter X_{ij} is a negative indicator,

$$A_{ij} = \frac{\max\left(X_j\right) - X_{ij}}{\max\left(X_j\right) - \min\left(X_j\right)}. \tag{7}$$

Among equations (6) and (7), X_{ij} indicates the value of the j_{th} index of the i_{th} county, A_{ij} represents the normalized index value, $\min(X_j)$ refers to the minimum value of item j, and $\max(X_j)$ stands for the maximum value of item j index.

Specific calculation steps are as follows.

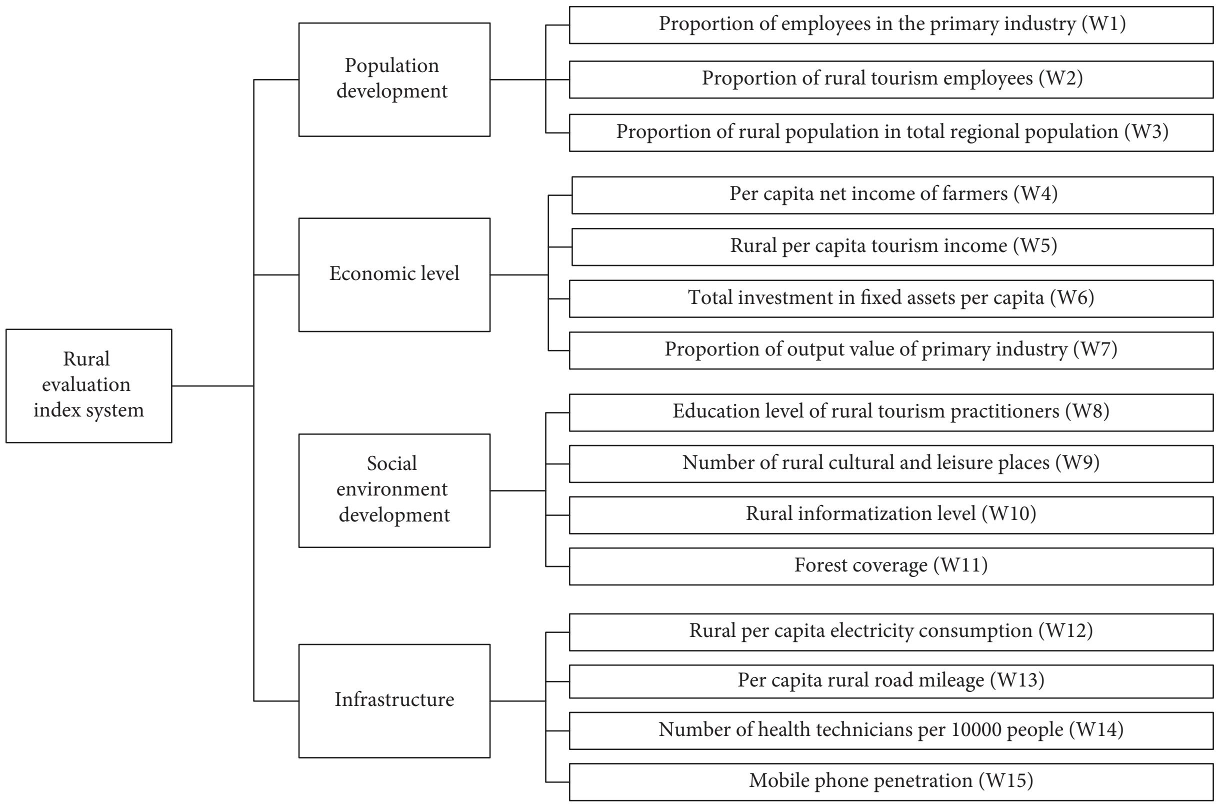

Figure 3: Rural evaluation index system of rural tourism destination.

Step 1. Calculate the specific gravity value.

$$B_{ij} = \frac{A_{ij}}{\sum_{i=1}^{m} A_{ij}}. \tag{8}$$

Step 2. Calculate entropy.

$$e_j = -K\sum_{i=1}^{m} B_{ij} \ln B_{ij}\left(\text{among them, } K = \frac{1}{\ln m}, \text{j} = 1, 2, 3 \ldots \text{n}\right). \tag{9}$$

Step 3. Calculate the weight of indicators.

$$W_j = \frac{1 - e_j}{\sum_{j=1}^{n}\left(1 - e_j\right)}. \tag{10}$$

The rural index of rural tourism destination can be calculated as

$$\text{RX}_i = \sum_{j=1}^{n} A_{ij} W_j. \tag{11}$$

Among equations (8)–(11), A_{ij} says the standardized index value, B_{ij} is the specific gravity value, m equals to the total amount of county units, W_j indicates the weight of j indexes, and RX_i represents the rural index of i county unit, where the rural index will change with the change of the value. E_j is the entropy value, and n stands for the total number of indicators.

2.5. Spatial Autocorrelation Analysis. Global spatial autocorrelation analysis can describe the spatial characteristics of attribute values of research objects in the whole region. It can also measure the overall spatial correlation between different regions and the degree of difference between them. The mathematical expectation of global Geary's C is constant 1, which is not affected by spatial weight, observation value, and sample size, resulting that the statistical performance of Geary's C is worse than that of global Moran's I. Only the distance-defined spatial proximity method can be adopted to form the weight matrix from Local Getis-Ord *G*, which performs poorly when identifying negative spatial autocorrelation. Moran's I index is a global index used to measure spatial autocorrelation, and its calculation is as follows:

$$I = \frac{n}{S_o} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij} Z_i Z_j}{\sum_{i=1}^{n} Z_i^2}. \tag{12}$$

In equation (12), Z_i refers to the deviation between the attribute of element I and its average value, W_{ij} represents the spatial weight, n stands for the total number of elements, and S_o indicates the aggregation of all spatial weights. When the global Moran's I changes between 0 and 1, it means positive spatial correlation; otherwise, it means negative spatial correlation.

The local Moran's I index, also known as clustering and outlier analysis, is different from the global Moran's I. The global Moran's I index is only used to judge whether the global elements have spatial correlation, but the local

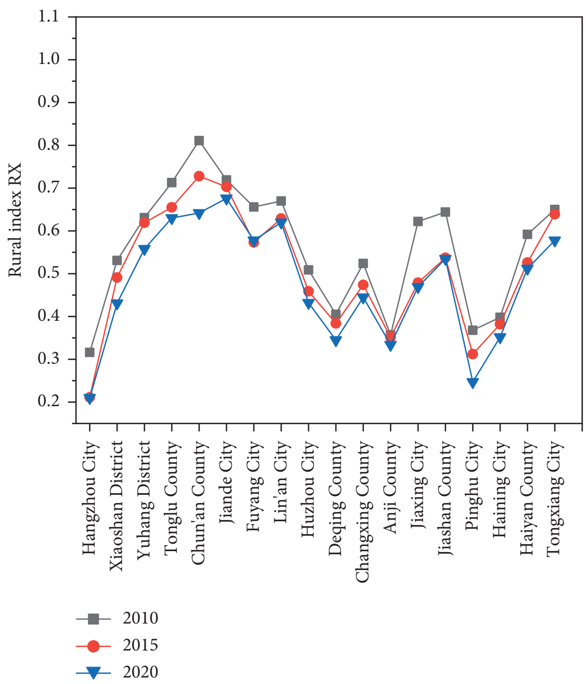

Figure 4: Rural index of counties in “Hangjiahu area,” Zhejiang Province (x: names of the counties in “Hangjiahu area,” Zhejiang Province; y: rural index).

Moran’s I can be used to show the spatial correlation among various elements. The calculation is as follows:

$$I = Y_i \sum_{i=1}^{n} W_{ij} Y_j. \tag{13}$$

In equation (13), Y_i and Y_j are the standardized values of the observed values of spatial unit *i* and unit *j*, respectively, and W_{ij} indicates the spatial weight. Local spatial autocorrelation can analyze the relationship between a certain point and the surrounding points of the cluster, including high-high clustering, high-low clustering, and low-high clustering.

3. Results

3.1. Overall Evaluation of Rural Tourism in “Hangjiahu Area”. Figure 4 shows the calculation of the rural index of “Hangjiahu area” in Zhejiang Province in 2010, 2015, and 2020.

Figure 4 reveals that from 2010 to 2020, the overall trend of rural index of all county units included in the “Hangjiahu area” of Zhejiang Province is decreasing year by year, and the rural differences among these county units are also gradually weakening. The rurality index of 18 counties in the “Hangjiahu area” of Zhejiang Province is the highest in Chun’an County during 2010–2015, with values of 0.811 and 0.728, respectively. Also, the lowest indexes are all in Hangzhou City, with values of 0.316 and 0.211, respectively. The highest index in 2020 is in Jiande, with a value of 0.676, and the lowest is in Hangzhou. This indicates that the rurality index of Hangzhou is the lowest. In order to deeply analyze the regional differences of rural characteristics in the “Hangjiahu area” of Zhejiang Province and the evolution of polarization degree in time sequence in these areas, a descriptive statistical analysis is made on the rural characteristics index, as Figure 5.

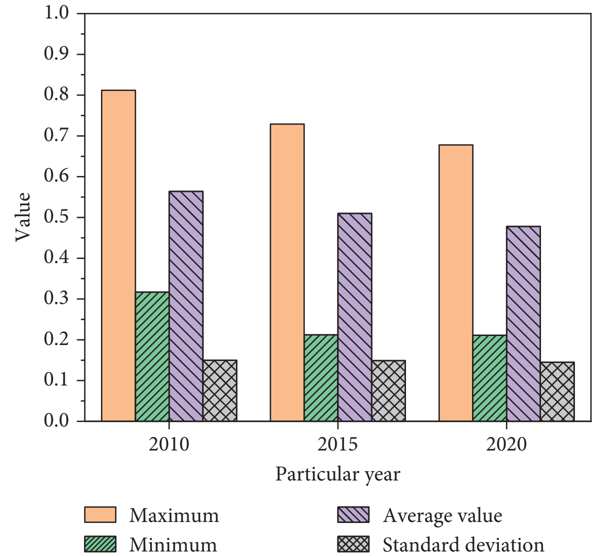

Figure 5: Evolution of regional difference of county rural index in the “Hangjiahu area,” Zhejiang Province (x; particular year; y: the values of maximum, minimum, average, and standard deviation of rural index).

Figure 5 indicates that from 2010 to 2020, the maximum value of rural index of all county units in the “Hangjiahu area” of Zhejiang Province decreased from 0.812 in 2010 to 0.678 in 2020, the minimum value decreased from 0.317 in 2010 to 0.211 in 2020, and the average value decreased from 0.564 in 2010 to 0.478 in 2020. Therefore, the results show that the impact of rural tourism development on rural economy and society is increasing. The standard deviation of rural index of each county unit is also decreasing year by year, from 0.15 in 2010 to 0.145 in 2020, which indicates that the rural difference in the “Hangjiahu area” of Zhejiang Province is decreasing and the difference is weakening year by year.

In order to further analyze the spatial differentiation and spatial pattern evolution of rural areas in the Hangzhou-Jiaxing-Huzhou region of Zhejiang Province from 2010 to 2020, a global Moran’s I statistical test was carried out on the rural indexes in the Hangzhou-Jiaxing-Huzhou region in 2010, 2015, and 2020. Figure 6 reveals the results.

Figure 6 notes that the Moran’s I indexes of rural areas ranged from 0.038 to 0.052 from 2010 to 2020, all of which were positive, and the overall trend was increasing year by year, and the significance level of *z* test was $P < 0.5$. The research results showed that the rural index of the Hangzhou-Jiaxing-Huzhou area in Zhejiang Province appeared with an aggregation distribution state in space. From 2010 to 2020, with the continuous development and advancement of rural tourism and urbanization, the differences between counties and cities in the Hangzhou-Jiaxing-Huzhou area of Zhejiang Province are shrinking year by year.

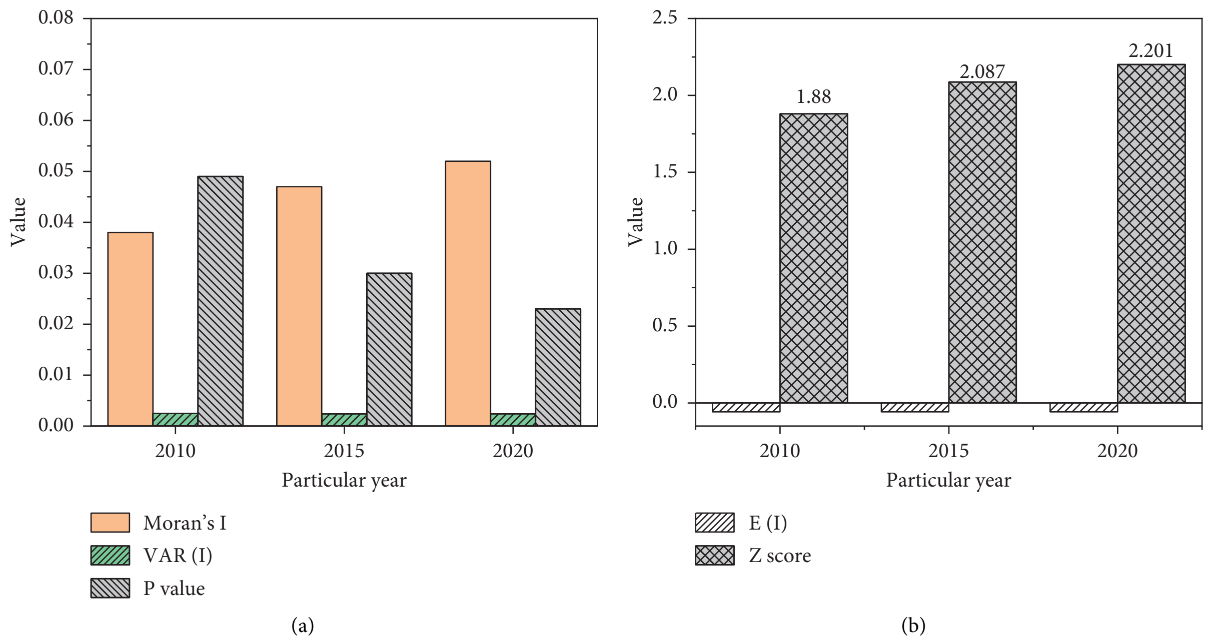

Figure 6: Global Moran's I statistical test results. (a) Correlation test results (x: particular year; y: values of global Moran's I statistical test); (b) significant test results (x: particular year; y: values of Z-score).

3.2. Index Weight Results of Neural Network Model. When using the ANN model to evaluate the spatial pattern of rural tourism, it is necessary to calculate and sort the weights of each index. Table 1 presents the weights of each index.

Table 1 indicates that the weight of employees in the primary industry (W1) is 0.523, that of rural tourism professionals (W2) is 0.462, that of rural per capita tourism income (W5) is 0.464, that of primary industry output value (W7) is 0.394, that of rural informatization level (W10) is 0.467, that of rural road mileage per capita W (13) is 0,431, and that of mobile phone population rate (W15) is 0.412. Also, the weight values of these eight indicators are relatively large, which shows that these eight indicators have a great influence on the rural nature of rural tourist destinations.

Table 1: Weight value of rural evaluation index of rural tourism destination.

Evaluating indicator	Weight
W1	0.523
W2	0.462
W3	0.281
W4	0.181
W5	0.464
W6	0.192
W7	0.394
W8	0.123
W9	0.178
W10	0.467
W11	0.242
W12	0.518
W13	0.431
W14	0.139
W15	0.412

3.3. BPNN Simulation Results. After the completion of the network training, the feasibility of the established evaluation system of rural tourism in the "Hangjiahu area" of Zhejiang Province is simulated by using the neural network toolbox in MATLAB software and 10 groups of samples. Figure 7 shows the comparison between the evaluation results obtained by the network and the actual evaluation results.

After the BPNN evaluation model for rural tourism destination being verified and tested, Figures 7 and 8 indicate that the actual value output is basically consistent with the expected value, and the difference between them is very small. By analyzing the BPNN evaluation error curve, it is found that the evaluation error and the actual error range are within 0.08%, which proves that the BPNN algorithm has good accuracy. Therefore, the BPNN evaluation model for rural tourism destination implemented here can make a good evaluation of rural tourism space.

3.4. Analysis of Influencing Factors of Rural Tourism Spatial Pattern Evolution

3.4.1. Factor Analysis of Industrial Structure Adjustment. Correlation analysis is made between the proportion of employees in the primary industry (W1), the proportion of rural tourism professionals (W2), the per capita tourism income in rural areas (W5), the proportion of the output value of the primary industry (W7), and the rural index in each county and city. Table 2 lists the results.

Table 2 and Figure 9 signify that Pearson correlation coefficients of rural per capita tourism income (W5) and rural index in 2010, 2015, and 2020 are −0.582, −0.654, and −0.703, respectively, and the test results of significance level are 0.012 (less than 0.05), 0.005 (less than 0.01), and 0.01,

Table 2: Correlation and significance analysis of rural index.

Age	Evaluating indicator	Pearson correlation	Significant (bilateral)
2010	W1	0.752^{**}	0.002
	W2	-0.529^{*}	0.021
	W5	-0.582^{*}	0.012
	W7	0.711^{**}	0.001
2015	W1	0.746^{**}	0.000
	W2	-0.604^{**}	0.006
	W5	-0.654^{**}	0.005
	W7	0.681^{**}	0.003
2020	W1	0.725^{**}	0.000
	W2	-0.609^{**}	0.003
	W5	-0.703^{**}	0.000
	W7	0.676^{**}	0.001

Note. *means a significant correlation at 0.05 level (bilateral); **means a significant correlation at 0.01 level (bilateral).

respectively. In addition, Pearson correlation coefficients of rural tourism professional ratio (W2) and rural index in 2010, 2015, and 2020 are -0.529, -0.604, and -0.609, respectively. The test results of significance level are 0.021 (less than 0.05), 0.006 (less than 0.01), and 0.003 (less than 0.01), respectively. Pearson correlation coefficients of the proportion of primary industry output value (W7) and rural index in 2010, 2015, and 2020 are 0.711, 0.681, and 0.676, respectively, and the test results of significance level are 0.001 (less than 0.01), 0.003 (less than 0.01), and 0.001 (less than 0.01), respectively. Pearson correlation coefficients of the proportion of employees in the primary industry (W1) and rural index in 2010, 2015, and 2020 are 0.752, 0.746, and 0.725, and the test results of their significance levels are 0.002, 0.000, and 0.000, respectively. There is a significant positive correlation between the proportion of employees in the primary industry (W1) and the rural index. From 2010 to 2020, the per capita rural tourism income (W5) and the proportion of rural tourism professionals (W2) in every county and city in the Jiahu area of Hangzhou are also increasing year by year. Moreover, the growth of surrounding counties with Hangzhou as the core is most obvious. This fully shows that the development of the primary industry is not paid enough attention to, so it has become one of the important factors that restrict the rural level in the Hangzhou-Jiaxing-Huzhou area. Results indicate that the development process of urbanization can be directly promoted by the tourism industry, but it will also be accompanied by the decline of the rural level.

3.4.2. Analysis of Traffic Factors. Correlation analysis is made between the per capita rural road mileage (W13) and the rural index in each county and city. Table 3 displays the results.

Table 3 presents that the Pearson correlation coefficients of the evaluation index of rural road mileage per capita (W13) and rural index in 2010, 2015, and 2020 are -0.474, -0.573, and -0.672, respectively, and the significance level test results are 0.048, 0.015, and 0.013, respectively, which are all less than 0.05. From 2010 to 2020, the per capita rural road

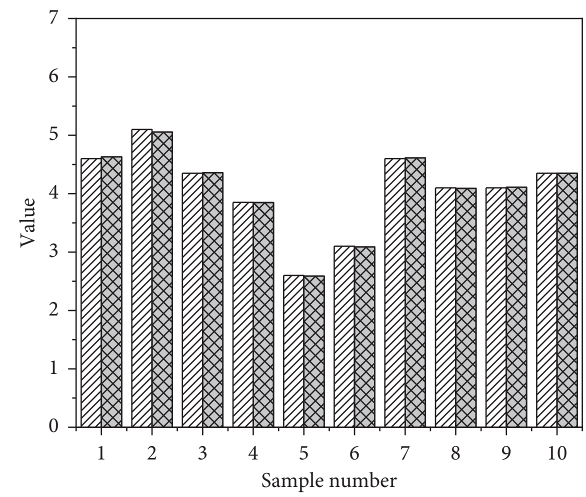

Figure 7: Performance comparison of BPNN algorithm (x: the orders of the samples; y: values of output and actual evaluation).

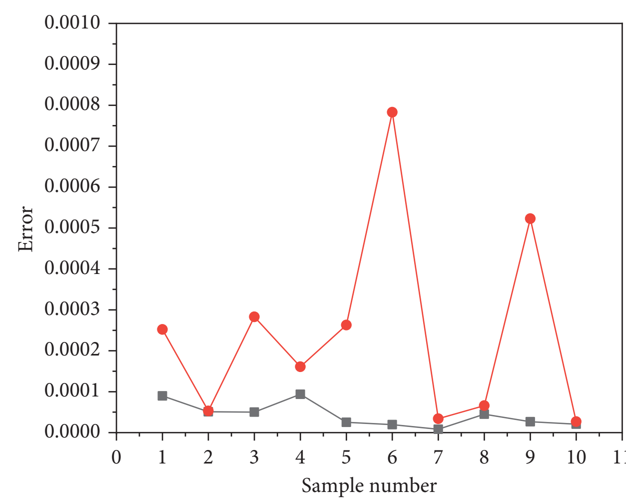

Figure 8: BPNN model training and error comparison (x: the orders of the samples; y: errors in training and test).

mileage (W13) of all counties and cities in this region showed a trend of increasing year by year, and the most obvious increase was in the surrounding counties with Hangzhou as the center. The rural index in this region showed a declining trend and an agglomeration distribution trend, which forms a cold spot with Hangzhou as the center. This fully shows that the accessibility of road traffic can promote the development of commercial and economic activities to a certain extent, so as to lower the rural level. Therefore, the improvement of traffic factors has a significant impact on the rural level.

3.4.3. Analysis of Social Environment Factors. The correlation analysis is made between the three factors of mobile

Table 3: Correlation and significance analysis of rural index.

Evaluating indicator	Age	Pearson correlation	Significant (bilateral)
W13	2010 years	−0.474*	0.048
	2015	−0.573*	0.015
	The year of 2020	−0.672*	0.013

Note. *indicates a significant correlation at 0.05 level (bilateral).

Table 4: Correlation and significance analysis of rural index.

Year	Evaluating indicator	Pearson correlation	Significant (bilateral)
2010	W10	−0.470*	0.047
	W12	−0.498*	0.035
	W15	−0.562*	0.014
2015	W10	−0.552*	0.013
	W12	−0.502*	0.039
	W15	−0.688**	0.003
2020	W10	−0.658*	0.016
	W12	−0.598*	0.035
	W15	−0.706**	0.001

Note. *means a significant correlation at the 0.05 level (bilateral); **means a significant correlation at the 0.01 level (bilateral).

phone penetration rate (W15), rural per capita electricity consumption (W12), and rural informatization level (W10) and the rural index. Table 4 and Figure 10 display the results.

Table 4 and Figure 10 signify that the Pearson correlation coefficients between the three factors of mobile phone penetration rate (W15), rural per capita consumption (W12), and rural informatization level (W10) and the rural index are -0.470, -0.552, -0.658; -0.498, -0.502, -0.598; and -0.562, -0.688, -0.706. The test results of significance level are 0.047, 0.013, 0.016; 0.035, 0.039, 0.035; and 0.014, 0.003, 0.001, respectively, all of which are less than 0.05. Rural informatization level (W10) is negatively correlated with rural index, and the negative correlation tends to increase. Rural per capita consumption (W12) is negatively correlated with rural index, and the negative correlation tends to increase. The mobile phone penetration rate (W15) is negatively correlated with rural index. Also, this negative correlation shows a growing trend. From 2010 to 2020, the rural informatization level (W10), mobile phone penetration rate (W15), and rural per capita electricity consumption (W12) in all counties and cities are increasing year by year. Conclusion is drawn that a strong modern civilization can strengthen a region's commercial awareness and the concept of market economy. It can also promote the presentation of more capital, technology, and talent advantages, to lower the rural level. Therefore, social and environmental factors will have a significant impact on the rural level.

In the future development of rural tourism, more attention should be paid to the construction of rural ecological environment and the protection of rural cultural characteristics. Therefore, creating an upgraded version of beautiful countryside is a policy that helps to protect rurality. In the process of creating an upgraded version of the beautiful countryside, the government should establish a sense of

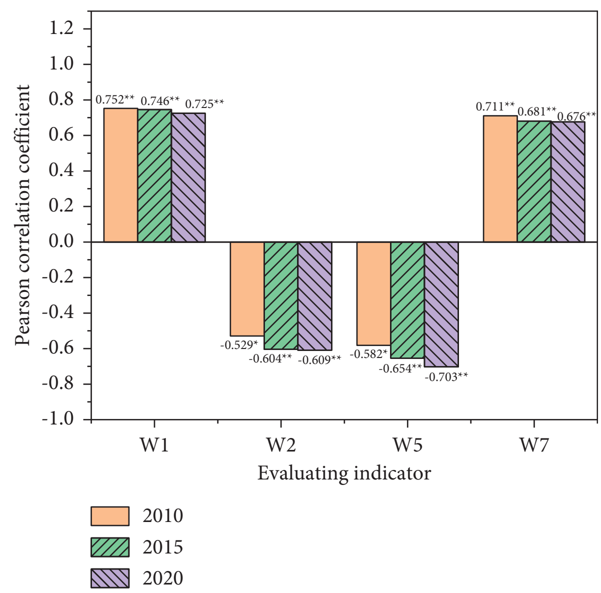

Figure 9: Correlation trend of rural index from 2010 to 2020 (x: evaluating indicator; y: Pearson correlation coefficient).

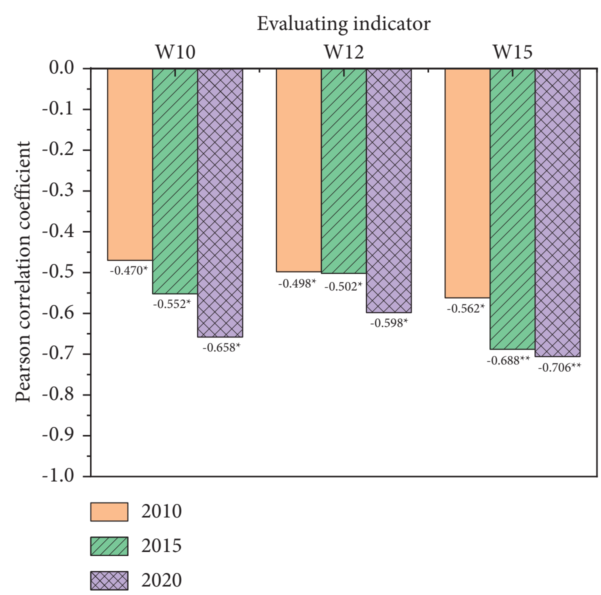

Figure 10: Correlation trend of village index from 2010 to 2020 (x: evaluating indicator; y: Pearson correlation coefficient).

regulation, scientifically formulate rural construction plans, fully demonstrate the connotation of the countryside, realize the unification of the economic value, social value, and ecological value of the countryside, and make "green" as the main tone of beautiful countryside. In the process of constructing the beautiful countryside, the green development is always the main line. The transformation should be gradually realized in the agricultural production mode, rural construction mode, and farmers' lifestyle. Meanwhile, the basic principle should keep still, which is adhering to the organic combination of local characteristics and ecological environmental protection requirements and carrying out differentiated construction according to local conditions.

Based on maintaining the landscape and pastoral scenery and historical and cultural characteristics of each village, the pattern of "one village, one product, one industry, one village, one rhyme" is formed to realize the sustainable development of the countryside. Besides, in the process of construction of beautiful countryside, the government should change its role, from the leader of rural construction to the guide and the coordinator, and the government should constantly strengthen the propaganda and education of all levels of society and improve the cognitive level of all levels of society on rural value according to the local traditional history, cultural accumulation, resource endowment, ecological environment, and other characteristics through various forms, using various platforms and carriers.

4. Conclusion

With the rapid development of urbanization and rural tourism, great changes have taken place in the traditional rural structure and lifestyle, followed by the gradual disappearance of the original unique rural nature and importance of the countryside. Based on rural characteristics, factors such as social environment development, population development, and economic development are taken as the research indicators, and the evaluation index system of rural tourism destination is constructed. The spatial pattern of rural tourism is empirically studied with examples, the rural index of the region in 2010, 2015, and 2020 is calculated, and the model is simulated and analyzed by MATLAB software. Finally, the spatial autocorrelation method is used to analyze the evolution characteristics of rural tourism spatial pattern. The research results show that by analyzing the evaluation error curve of BPNN, the evaluation error and the actual error range are within 0.08%, which proves that the BPNN algorithm has good accuracy. The BPNN evaluation model for rural tourism destination implemented here can make a good evaluation of rural tourism space. From 2010 to 2020, the proportion of employees in the primary industry and the penetration rate of mobile phones are the decisive factors in the adjustment of industrial structure and social environment, respectively. Rural tourism income per capita and the proportion of the output value of the primary industry also have a certain impact on the rural evolution. A certain guiding significance is provided for the sustainable development of rural tourism, but the deficiency lies in that only each county and city in Hangzhou Jiahu District is taken as the research object due to the availability of data. Some internal differences among county-level administrative regions have not been fully studied. In the future improvement research of BPNN, the variable coefficient method can also be used to modify the connection weight to accelerate the convergence speed of the network.

Data Availability

The labeled dataset used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

The Influence of Artificial Intelligence on Art Design in the Digital Age

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With the advancement of technology represented by artificial intelligence, art creation is becoming increasingly rich, and content expression is intelligent, interactive, and data-driven, making the relationship between technology, art, and people increasingly close and bringing opportunities for the development of emerging interaction. Artificial intelligence technologies aim to perfectly replicate the human mind by enabling natural responses based on the surrounding environment, decoding emotions, and recognizing human traits within the energy range. Driven by AI technology, interactive art no longer focuses on a single audiovisual sensory experience but rather on integrated artistic expressions that are highly interactive, kinetic, and emotional, based on the study of natural human behavior and integrated senses, combined with intelligence. In this paper, we first sort out the intersection of AI technology development and interactive art expression streams on the timeline based on historical development and analyze the deconstructive relationship between the two from the macroperspective of the historical development of technology and art. First, based on the conceptual connotation, development history, technical application, and singularity outlook of AI, we identify the current characteristics and development trends of interactive art; second, based on exploring the advantages of AI technology, we propose the impact of AI on the creative thinking, creative mode, and artistic experience of interactive art and establish the paradigm of interactive art creation in the context of AI. It solves the problem that experts are unable to quickly locate the category of painters when facing different styles of unsigned digital Chinese painting images in the authenticity identification task.

1. Introduction

In the Internet era, digital museums, digital libraries, and some related websites of Chinese painting and art have developed. As an important art relic, digitized Chinese paintings are slowly becoming known for their advantages of easy preservation and fast retrieval. Moreover, it is simple to digitize the Chinese paintings made on Xuan paper and turn them into digital Chinese painting images [1]. Therefore, the digitization of Chinese paintings is gradually becoming a new way to protect Chinese paintings. However, experts are unable to quickly locate the category of painters in the face of unsigned digital Chinese painting images of different styles in the task of authenticity identification, which affects the efficiency of identification [2]. Therefore, the classification of Chinese painting painters, as an important branch of digital Chinese painting authenticity-assisted authentication, has gradually become a hot spot for research in terms of its classification accuracy as well as automation. On the contrary, the prevalence of Chinese painting digitization has led to the difficulty of controlling the quality of digital Chinese paintings in Chinese painting databases [3]. Moreover, in the era of big data, the sources of digitized Chinese paintings have increased, and the authenticity of their contents has gradually become a focus of attention. Traditional identification methods mainly rely on the rich experience of identification experts [4]. Due to the subjectivity of traditional identification methods and the lack of objective referenceable indicators, there are limitations in the efficiency and accuracy of their identification in the face of the new generation of information technology forgery methods [5]. Therefore, a digital Chinese painting authenticity-assisted identification tool with a high degree of automation and accuracy is particularly necessary. At the beginning of the twentieth century, the great development of photography, communication, and other media technologies hit Western art, which was based on realism at that time and brought an unprecedented sense of crisis to art workers, and more and more artists realized that the only way to establish a new artistic status was to innovate, thus giving birth to numerous art schools [6].

Interactive art is rooted in the artistic trends of Cubism, Futurism, and Dadaism, which confronted traditional art and laid a solid foundation for the development of contemporary digital interactive art [7]. The relationship between artificial intelligence and interactive art can be traced back to the birth of the concept of "artificial intelligence" in 1956. Both interactive art and artificial intelligence technology are based on computer technology, and their inherent connection between technology and art has established the inevitability of their development and integration since their birth [8]. In the early stage of interactive art development, interactive artists customized the rules of interaction through technical research and attracted participants into the art world they created by changing the physical form, emphasizing the satisfaction of form and technical application and ignoring the experience and cognitive mode of participants. In the 1980s, computer psychology gradually developed into a cognitive discipline, artificial neural network research developed rapidly, and breakthroughs in speech recognition and machine vision technology brought artificial intelligence research into its formative years [9]. The research concept of experience formally entered the sight of artists and technology workers, and focusing on human interaction experience became the key point of interactive art expression. Therefore, as people pursue the sense of experience and entertainment in interactive art, the object of interactive art creation shifts from the study of objects to the study of human behavior, and the connection between science and art becomes closer. In the twenty-first century, with the development of deep learning technology of artificial intelligence, artificial intelligence research has entered a golden period of application, and human-computer interaction technologies such as intelligent voice interaction, machine recognition, and virtual reality based on artificial intelligence technology have advanced by leaps and bounds, which is pivotal to the development of human-centered interactive art [10]. Intelligence, nature, learning, and abiotic intelligence are new technologies and concepts carried by the development of artificial intelligence, which support the creation of contemporary digital intelligent interactive art and influence the aesthetic trends of the public and the creative thinking of artists. This paper focuses on how intelligent technology under the domination of artificial intelligence changes interactive art expression from the level of thinking, means, and experience logic and proposes a paradigm of interactive art expression under the influence of artificial intelligence technology [11].

The fusion of artistic creativity and technologically advanced productivity provides the creative impetus for the sustainable development of art and HCI technology in the future. Overall, artificial intelligence is much more than a simple technical means for art creation; it is more of a reshaping of art creation thinking and an impact on human cognition. We collect materials related to artificial intelligence, film and television creation, film and television market management, and film and television consumer experience, including books, newspapers and magazines, dissertations, theoretical works related to artificial intelligence, and film and television to provide comprehensive theoretical support for the dissertation, draw on and absorb research results from sociology, psychology, management, law, film, television, information technology, etc. The paper combines macro- and microanalysis to provide a more profound interpretation of the topic. This paper innovatively sorts out the influence of AI on interactive art expression through deconstruction and reconstruction thinking, analyzes how AI deconstructs the original model of interactive art creation in terms of technology and thinking, then analyzes the influence of AI on interactive art expression in terms of time, space, and natural logic, and establishes its application paradigm. This paper provides a new practical direction for interactive art creation. By selecting appropriate statistical methods, different external environmental factors are analyzed to understand the changes in the shape and quantity of the distribution, the relationship between variables, etc. This research method has a very obvious indirectness and it is less disturbed and easier to implement. Mainly through the analysis of statistics, statements, data, and other information published by relevant departments, we understand the development status of the film and television industry under the influence of AI, including the status of AI companies, products, and technology development related to the film and television industry and the status of AI applications in the film and television industry, and anticipate its future direction. The contributions of this work can be summarized as follows:

(1) We first sort out the intersection of AI technology development and interactive art expression streams on the timeline based on historical development and analyze the deconstructive relationship between the two from the macroperspective of the historical development of technology and art
(2) Based on exploring the advantages of AI technology, we propose the impact of AI on the creative thinking, creative mode, and artistic experience of interactive art and establish the paradigm of interactive art creation in the context of AI
(3) The proposed method can be used to quickly locate the category of painters when facing different styles of unsigned digital Chinese painting images in the authenticity identification task

2. Related Work

Global research on artificial intelligence has been carried out long before, and AI cannot be called a new science. In the early development of AI, with the later development of new technologies, AI technology in recent years has made new breakthroughs in a number of areas and empowered various industries [12]. Due to the increasing frequency of AI in public life and practical applications in recent years and the gradual maturation of the technology development, the literature research is mostly focused on journal reports, and the research content involves the application of AI as a film content element and the impact of AI on the production, market management, and consumer experience in the film and television industry chain [13]. The features of Chinese paintings are used as the direct basis for intelligent classification, and the amount of information they contain directly affects the classification results. Among the features of Chinese paintings, wavelet features are used for classification [14]. The feature values that can express the characteristics of paintings are proposed as the basis of classification using the information theory. The local and global features of the paintings are used to study the authors of Chinese paintings. With further research, the artistic style of the painter becomes an important factor in the identification of the painting [15]. Features describing the painter's artistic style such as color, texture, and brushstroke also gradually became an important basis for the classification of painters. Semantic classification is achieved using the image color and shape features of the target. Color histograms, color coherence vectors, and autocorrelation texture features are used and classified into two categories according to brushwork and painting [16]. The ink color features of brush strokes and brushwork of Chinese paintings are extracted as the basis of classification. A multiscale grayscale covariance matrix method is proposed to extract texture features and complete the classification recognition of Chinese paintings [17]. Although the image content-based features such as color, texture, and brushstroke can better express the artistic style of the painting and improve the classification accuracy, the pure underlying features, again, directly lead to unsatisfactory classification results and have limitations. In addition, there are relatively few existing research works on the fusion of multidimensional features based on image content, fusing the underlying color and shape features of Chinese paintings and using the fused features as the basis of Chinese painting research [18]. The above studies fuse fewer underlying features and cannot provide a sufficient basis for analysis.

In addition to feature merit affecting intelligent classification results, the classification method and its treatment of features are also the key to intelligent classification [19]. A Monte Carlo convex packet model is used to achieve the classification of Chinese paintings. The abovementioned classification methods based on statistical models depend on the goodness of features, and the cumbersome process of tuning parameters reduces the automation of classification. They extracted wavelet features of Chinese paintings and completed the classification of Chinese paintings using support vector machines. The above machine learning-based classification methods improved the parameter tuning process, but the feature quantification was not accurate enough. With the study, it was found that deep learning-based classification methods not only provide high-level semantic representation of image features, but also the end-to-end design of this class of methods improves the automation of classification. Picasso's brushstroke features are quantified using recurrent neural networks (RNNs), and painterly classification is achieved. Deep convolutional neural networks (DCNNs) are used to achieve the description of texture features of ancient paintings and the classification of ancient paintings. CNN is used to extract the brushstroke features in ink painting to quantify the style of ink painting and complete the classification [20]. Deep aggregation structure is used to improve the recognition ability of CNN models. The residual mechanism is proposed to increase the depth of the network by the jump connection and residual mechanism to improve the network classification performance. The feature rescaling module is proposed to emphasize the importance of different image feature channels. The convolutional block attention mechanism module (CBAM) is proposed to enhance the ability of CNN models to extract features. Therefore, it has become an important trend in the intelligent classification to introduce enhancement modules to improve the learning ability of the network based on deep learning networks.

In the 1960s and 1970s in the Western art field, research on theories related to artificial intelligence and interactive art had already begun, and many new artistic concepts were proposed, such as "artificial life art," "cyber art," and "natural intelligence" [21]. For the first time, it explores artists and their works who are working at the frontiers of scientific research and emerging technologies. The book is organized according to scientific disciplines and technological categories, discussing the in-depth relationship between art and science and technology, such as artificial intelligence and robotics, and exploring new possibilities for uncovering artists' work. It boldly predicts the next stage of artificial intelligence during the technological singularity, when human intelligences will merge with machine intelligences that greatly enrich the human brain with a faster, more accurate, larger storage, stronger memory, and efficient data-sharing capabilities. It explains the disruption of production, life, and even art by approaching singularity AI technologies, nano-life technologies, etc. It summarizes the history of the intertwining of art and technology, outlines the evolution of digital art since the 1980s, and provides a vision of future artistic expression, raising questions about audience interaction, artificial intelligence, politics, and social behaviorism through an analysis of artists' digital artworks. The third edition of this work, in 2015, expands the practice of digital art in the fields of virtual reality, augmented reality, and interactive public installations. The evolution of art forms such as interactive art-making, techno-intellectual art, and the art of dry computer and wet bio-fusion is discussed in detail. The way artificial and technological systems merge and the impact of future intelligence on artistic creation are explored, and the future evolution of biological self-evolution and the fate of art under the evolution of technological intelligence are looked into.

3. Artificial Intelligence-Based Art Design Feature Extraction

3.1. Image Features. Analysis for images is complicated by mathematical tools alone and requires finding feature values that can quantify the image information. Therefore, extracting image features and combining them with the feature learning capability of computers can improve the efficiency of image analysis. In this paper, the concepts and extraction methods of image stroke, texture, and color features are described in detail in the context of the research. Stroke features of an image are the lines that make up the content of an image, and lines are the primitives that make up the content of an image. In the image, the variation of lines can express the pose and outline of the image content. And the thickness and fiction of the lines can also convey different information. By studying the characteristics of lines on the surface of an image, a deeper meaning can be obtained. Edge detection algorithms are often used to detect line features of images. Therefore, applying edge detection algorithms to detect Chinese paintings can highlight the brushstroke features of Chinese painters. The edge detection algorithm usually relies on the edge detection operator, which is often used as the core operator for edge detection.

The detection principle is to detect the edges of an image by finding the absolute gray magnitude of the grayscale image. A series of grayscale vector information is generated when the edges of an image are detected using the reform operator. The Sobel operator usually computes two directions, horizontal and vertical, each with a convolution matrix of size 3×3, and any of the convolution matrices can be obtained by rotating another matrix by 90°. The expression is given in the following equation:

$$\widetilde{E}(n) = \sum_{i=1}^{I_k} \sum_{P \in Q}^{n} (\lambda t)^{n+1} e^{\lambda t} \log_n \frac{N_v}{N_n}, \tag{1}$$

where P is the original image and Gx and Gy are the convolution matrices in horizontal and vertical directions, respectively. The specific calculation formula is shown in equation where $f(x, y)$ is the grayscale value of the pixel point.

$$X = \frac{X_i - X_j}{\left(\sum_{i=1}^{n} \left(X_i - X_j\right)^2\right)}. \tag{2}$$

The calculation steps are as follows: (a) calculate the brightness difference of the image in different directions using two 3×3 matrices; (b) calculate the gradient value G of the pixels in the image at Gx and Gy, and the formula is shown as follows:

$$\begin{aligned} Q(x) &= \frac{\sum_{i=1}^{n} p\left(X = x_i\right)}{\log_2 (p(x))}, \\ Q(Y[X]) &= \frac{\sum_{i=1}^{n} p\left(X = x_i\right)}{q(x)}, \end{aligned} \tag{3}$$

and (c) calculate the gradient direction with the following equation:

$$\mathrm{Dis}\left(x_i, x_j\right) = \left(\sum_{i=1}^{n} \left(X_i - X_j\right)^q\right)^{1/q}. \tag{4}$$

In summary, the Sobel operator cannot distinguish between objects and backgrounds, and the image edges are intermittent, leading to its inaccurate results. If you want to improve the detection effect, you can increase the size of the convolution matrix, but such an operation will increase the computational effort. Usually, the image processed by the Sobel operator is not a grayscale image, which will make the image and the background not easily distinguishable. The Canny operator uses Gaussian filtering to remove image noise during edge detection, which makes the operator less susceptible to noise interference and can be applied to different scenes by setting different parameters. The Canny operator can fully reflect the strength of line edges in an image, making its detection fast and accurate.

3.2. Texture Characteristics. Texture features are surface attributes that describe an image or an image region. Regarding the extraction methods of texture features, as shown in Figure 1, they are divided into four main categories as follows:

(1) Statistical-based methods: texture features are random in the image region, but some regular characteristics of texture features can be mined using statistical methods. Statistical-based methods mainly study the grayscale distribution within the image region. Among them, the grayscale co-occurrence matrix is the most applicable, and the method uses the statistical feature values output from the grayscale co-occurrence matrix to represent the texture features of the image. The disadvantage is that it is not applicable to pixel-level texture classification tasks.

(2) Model-based methods: this class of methods considers that textures can be arranged according to some model distribution, and the relationship between texture primitives can be represented by the parameters of the model. The representative methods are mainly the random field method and fractal method. However, the disadvantages are obvious, as it does not match the actual image situation, and the texture is not adequately expressed. The fractal method mainly uses the relationship between image spatial location information and image grayscale to extract texture features of the image. The texture features extracted by this method have a

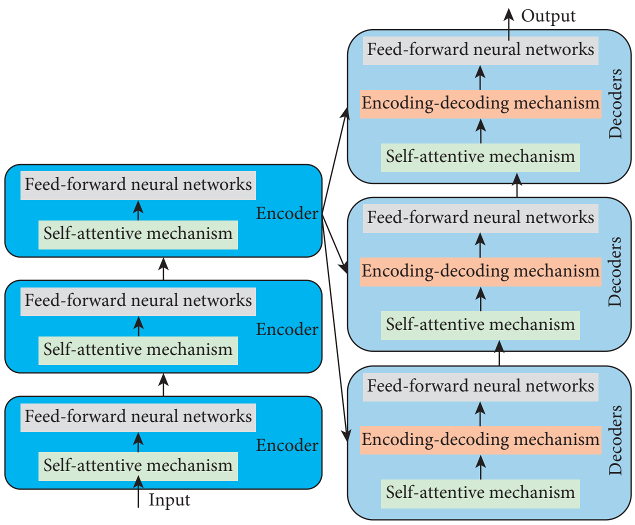

Figure 1: Texture feature extraction.

characteristic that different fractal dimensions are obtained when different image regions are extracted. Therefore, applying the fractal dimension to regional texture feature extraction can easily distinguish different image regions.

(3) Spectrum-based methods: this method is mainly based on spectral characteristics and multiscale analysis of texture features. The representative method is the wavelet transform, which was first proposed in the 1990s for the texture feature extraction, and then various improved methods based on wavelet transform were applied to various tasks of image processing.

(4) Structure-based method: the basic idea of this method is to analyze the texture primitives that make up the texture features so that the regularity of the texture features can be obtained.

Color features are important visual features in image processing. Among them, red, green, and blue (RGB), hue, saturation, and lightness (HSV) are the two most commonly used color spaces. The HSV color space is more intuitive than the RGB color space in color representation and is widely used in image processing tasks. The next part of this paper focuses on the commonly used color feature extraction methods.

(1) The color histogram is the proportion of each color in the image but ignores information about the spatial distribution of colors. This method is suitable for images without segmentation tasks. The color histogram is often calculated based on the HSV color space. First, the colors in the image are divided into different regions. Then, the number of pixels of different colors in each region is counted.

(2) The color set is proposed by Smith and is similar to the color histogram. First, the HSV color space needs to be transformed and the color space quantized into a histogram. Then, an index is created between the color space and the color components. This method has an advantage in retrieval speed when facing large-scale datasets.

(3) Color moments were proposed by Stricker et al. to express the color feature information in paintings by calculating the color first-order moments, second-order moments, and third-order moments of images, using the property that the color information is mainly concentrated in the lower-order moments.

(4) The color entropy is proposed by Zachary according to the definition of entropy mentioned by Shannon in the information theory, which combines the information entropy with the color histogram. The normalized color histogram can be set as h, and then the entropy of the image is expressed as

$$E(n) = \sum_{i=1}^{k} \sum_{P \in Q}^{n} (\lambda t)^{n+1} e^{\lambda t}. \quad (5)$$

3.3. Artificial Intelligence Deep Learning Models. Deep learning is a new research hotspot in the field of machine learning. Deep learning mainly emphasizes two points: (1) the depth of the model and (2) the mapping of feature information learned from shallow layers to a new feature space by reasonably increasing the number of network layers, which makes the classification more accurate. The VGG deep learning model, known as Visual Geometry Group, is a deepened version of AlexNet, designed by the Department of Science and Engineering at the University of Oxford, and is often used for tasks such as image classification and face recognition. Initially, the model was designed to clarify the relationship between the depth of the network and the accuracy of large-scale classification and recognition. The VGG model is composed of a convolutional layer, a pooling layer, and a fully connected layer. The basic computation of the convolutional layer is convolutional computation. Usually, the convolution operation requires setting parameters such as step size and padding. After the convolution operation, an activation function is usually introduced. The activation function is used to increase the ability of the network to fit various kinds of data by adding nonlinear capabilities. The following activation functions are commonly used (ReLU, Sigmoid, and tanh).

In addition, after the convolution operation of the input feature map using a large number of convolution kernels, the information of the feature map needs to be filtered, and the pooling is mainly operated using the maximum and average values. The main role of the fully connected layer is to fuse the feature information, which is usually connected in descending order. The commonly used VGG models have 16 and 19 layers, respectively, as shown in Figure 2.

The performance of the VGG network is positively correlated with depth, but increasing the depth of the network will reduce the learning ability of the network and cause a lot of parameters to reduce the efficiency. GoogLeNet is designed with twenty-two layers, but with one-twelfth of the parameters of AlexNet and one-fourth of VGG. The

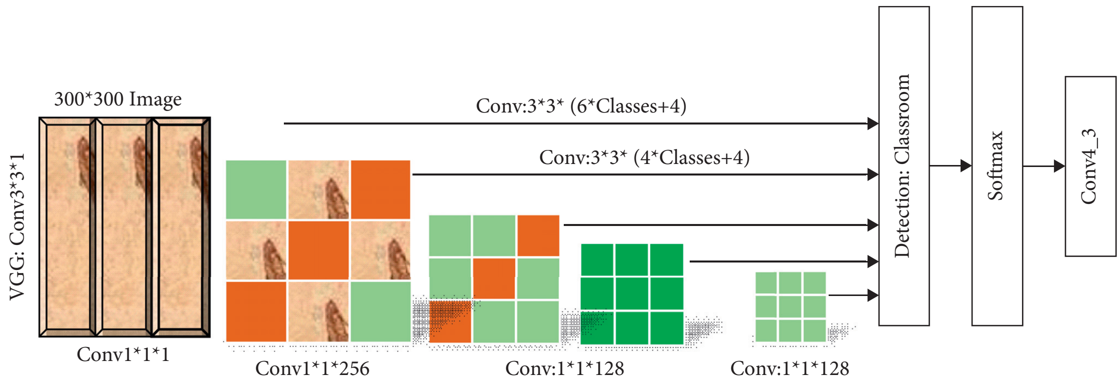

FIGURE 2: VGG-16 and VGG-19 network structures.

sparse network structure consists mainly of small convolutional kernels and 3×3 pooling layers, which can increase the network performance and ensure the efficient use of computational resources. In fact, after the network reaches a certain number of layers, the performance is negatively correlated with the number of layers, which leads to slow convergence and poor dataset performance. The residual mechanism in the residual network solves this problem by using multiple parameter layers to learn the residual representation between the input and output, that is, each learning depends on the previous learning result, preventing the performance of the network from degrading and making its learning incremental, instead of learning the mapping relationship between inputs and outputs in the ordinary order of the network structure. The advantage of the residual mechanism is that it largely solves the problem of network performance caused by increasing the number of layers. The structure of the residual mechanism is shown in Figure 3. The actual role of this layer is a nonlinear combination of features, which does not contain feature extraction and feature learning capabilities. In image processing, the number of parameters is reduced by using a small size of convolution kernels.

4. Analysis of Experimental Results

The experiments in this paper are based on the PyTorch deep learning framework for training and testing, with a NVIDIA GTX 1060 GPU, 8 GB of video memory, and Cuda version 10.1. The programming language is Python 3.6. Figure 4 shows the main parameters of the network training, and these parameters are used as the basic settings for the comparison experiments. To verify the performance of the proposed network classification in the context of Chinese painting classification, a five-fold cross-validation method is used, where the entire dataset is first divided into five disjoint subsets, and then four of them are randomly used as the training set and one as the test.

In the image block rejection process, the artistic target of the painting occupies a certain proportion of the whole frame, and there are blank and meaningless image blocks in addition to the artistic target because the blank image blocks and the image blocks containing a small number of artistic targets can provide less information and have the characteristic of low threshold. Therefore, the optimal contrast threshold is selected among [20, 60, 100, 140, 180, 220] using the grid search method. Among the random field methods, Markov random field models are very common, and they are used to establish a connection between textures and two-dimensional image fields. As can be seen from Figure 5, when the threshold value is 20, the presence of image blocks with invalid information leads to a low accuracy rate. As the contrast threshold value increases, the accuracy also increases. This is because blank image blocks and image blocks containing little invalid information are eliminated and image blocks containing valid information are retained. The accuracy is highest at the threshold value of 180. When the threshold value is 220, the accuracy starts to decrease because the blocks containing valid information are incorrectly rejected, which affects the network classification results. Therefore, the threshold is set to 180, and the specific effect of the image contrast-based image block rejection method on different subjects and images of different frame formats. From the results, it is shown that the method is good at removing blank and meaningless image blocks from paintings and retaining their artistic target details.

From Figure 5, it can be seen that the check-all rate and check-accuracy rate of color features are low among the four painters, which is because the color features are extracted with a single color variety in the paintings, and the color richness of the dataset is poor, making it difficult to achieve good classification results. This phenomenon is more obvious in Xu Beihong's paintings. As can be seen from the figure, the check-all rate and check-accuracy rate of Xu Beihong's paintings are obviously low, and the color features in Xu Beihong's paintings are not sufficiently characterized. Xu Beihong's paintings are mainly ink and wash, that is, black and white, lacking rich color expressions, which leads to lower check-all and check-accuracy rates. Thus, it can be seen that color features have a certain characterization ability, but the low color richness of traditional ink paintings and the little feature information available lead to the limitations of color features in the classification. Compared with the color features, the texture features have better characterization ability, and the texture features have better performance in two indexes, the check-all rate and the

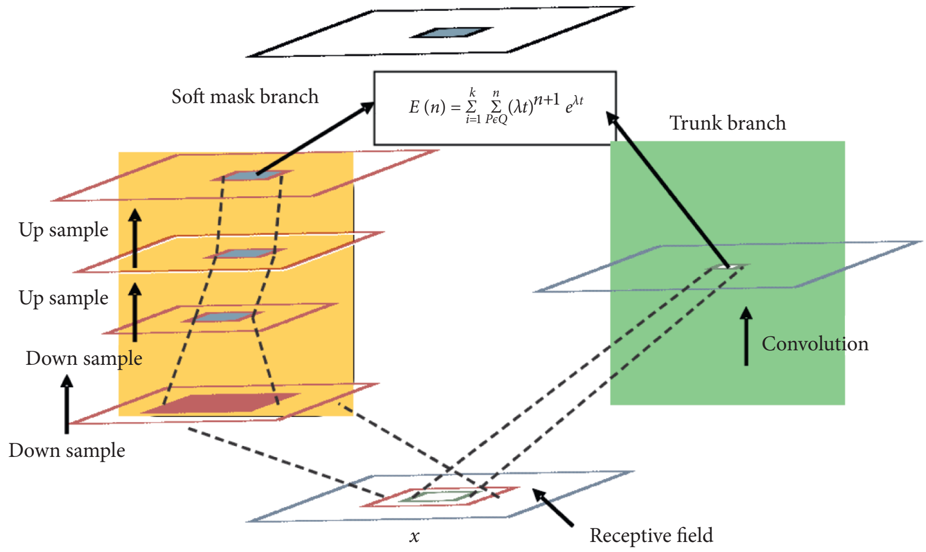

Figure 3: Residual mechanism structure diagram.

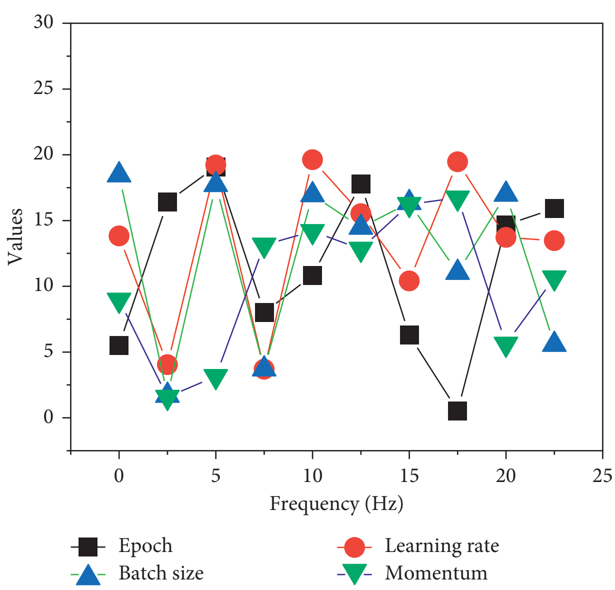

Figure 4: Network parameter data.

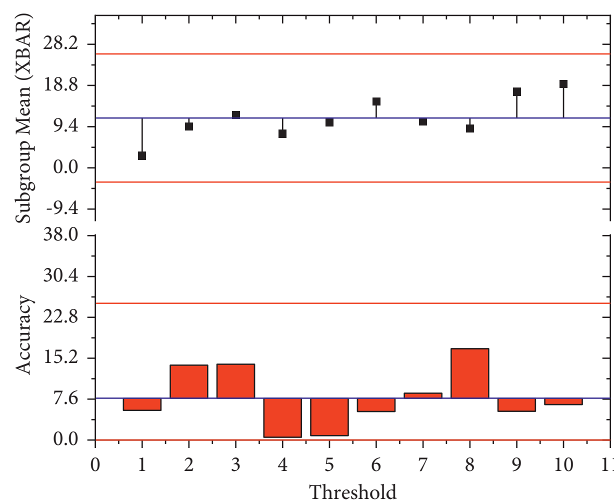

Figure 5: Different contrast thresholds.

check-accuracy rate. The texture feature map processed by the local binary mode algorithm removes the interference of the color feature of the painting itself, and the rotation invariance also reduces the influence of the different forms of the painting. In the four-painter classification experiments, the brushstroke features have better performance in two technical indexes, namely, the detection rate and the accuracy rate, compared with the color and texture features. It indicates that the brushstroke feature map processed by the edge detection algorithm can quantify the painter's artistic style by detecting the edge contours of the painter's brushwork. Finally, after fusing the three features, the check-all rate and check-accuracy rate of the four painters are significantly improved. It indicates that the fused features can make up for the deficiency of the color features' characterization ability; they have a deep semantic expression of the texture features; they retain the stroke features that can express the painter's artistic style. In summary, the fusion features are more suitable as the basis for the network classification. Furthermore, we discuss the effectiveness of the proposed network, and first argue whether the convolutional attention mechanism enhances the performance of the network. In the deep convolutional network, the commonly used attention mechanism modules are the SE module and CBAM module, and the experiments are mainly focused on these two modules to verify. The specific experimental results are shown in Figure 6.

From the figure below, it can be seen that the CBAM module slightly outperforms the SE module in terms of the average accuracy metric. It indicates that the SE module emphasizes the relationship between network channels but ignores the spatial information of the feature map. The natural logic expressed by intelligent interactive art follows the knowledge given to human beings by the natural human system. The social nature of human beings determines the

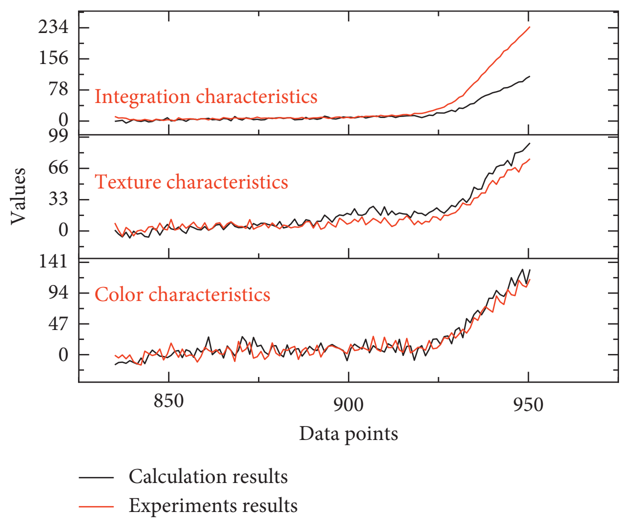

Figure 6: Experimental results of feature comparison.

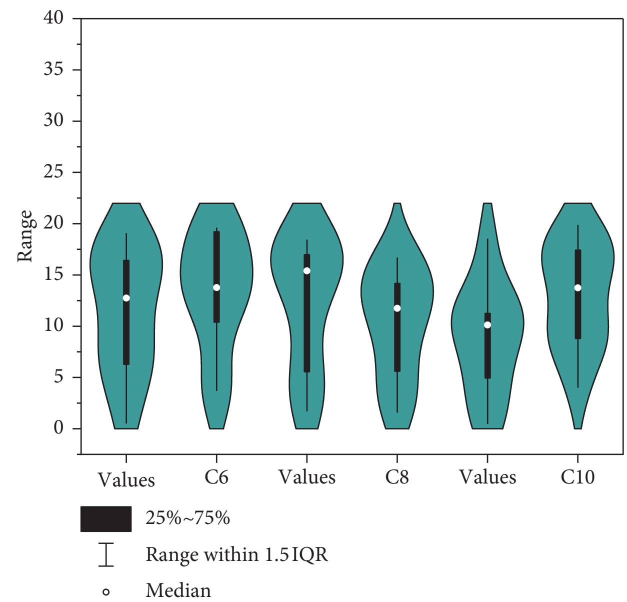

Figure 7: Experimentation with the number of CBAM modules.

transmission and dissemination of this experience so that we have today an extremely rich human cognitive experience and spiritual culture. The CBAM module compensates this deficiency by emphasizing the relationship between the feature map channels and learning the spatial information of the feature map through the spatial attention mechanism module. Compared with the base network, the CBAM module improves the feature extraction capability of the network and significantly enhances the performance of the network. Therefore, we incorporate this module into the network. After incorporating the CBAM module, the network has significantly improved in the average accuracy index, but during the experiment, we found that the performance of the network is directly affected when the number of CBAM modules incorporated into the network varies. Then, this paper compares the relationship between the number of CBAM modules and the performance of the network. The number of CBAM modules is incremented by the number of integrated modules in the experiment. As seen in Figure 7, when no CBAM modules are added to the network, the performance is similar to that of the ResNet-50 network. As the number of CBAM modules increases, the performance of the network gradually improves. When CBAM modules are incorporated in each residual unit, it not only increases the feature extraction capability of the network but also improves the classification performance of the network.

Usually, deep learning networks use ReLU as the activation function to increase the network's ability to be nonlinear. We experimentally compare the Mish activation function with the ReLU activation function. From the experimental results, we can see that there is a slight improvement in the average accuracy metric after using the Mish activation function. It indicates that the Mish activation function can propagate information better in the network and increase the nonlinear capability of the network, which makes its performance of extracting features enhanced. To verify the advantages of the proposed network in this paper, we compared the network with three current mainstream classification networks and measured them with the average accuracy metric. The results are shown in Figure 8. Compared with the VGG-16, GoogLeNet, and ResNet-50 networks, the proposed network outperforms the other mainstream networks in terms of the average accuracy metric. It indicates that the multibranch attention mechanism network proposed in this paper has advantages in feature extraction and fusion classification and is suitable for tasks such as intelligent classification of national paintings.

The fact that man comes from nature determines that man can never isolate himself from nature. When exploring the reasons for the rise of modern science in the West, he pointed out that the essence of the Renaissance was a revival of science and technology and proposed that Mr. Art and the son of Science belongs to the same essence of nature. Nature is the totality of all objective realities in the universe and the origin of all things. What distinguishes intelligent interactive art from other forms of interactive art is its adherence to natural logic and the intelligent technology put into practice. Human cognitive behavior consists of two parts; the first part is the action system that expresses the basic characteristics of human beings, which is generated in the environmental needs and collective behavioral examples, such as waving, nodding, and other human-specific physical actions; the second part is the cognitive system transmitted by language or words, which is the feedback mechanism generated by environmental needs and cognitive evolution, and this feedback mechanism, through the processing of external information, produces knowledge that combines speech, text, emotion, physical objects, and specific internal environmental information. As the aesthetic subject of intelligent interactive art, the human being completes the emotional transmission of intelligent interactive art. In this process, artificial intelligence provides visitors with human basic movements and cognitive recognition conditions under the human feedback mechanism, completes the

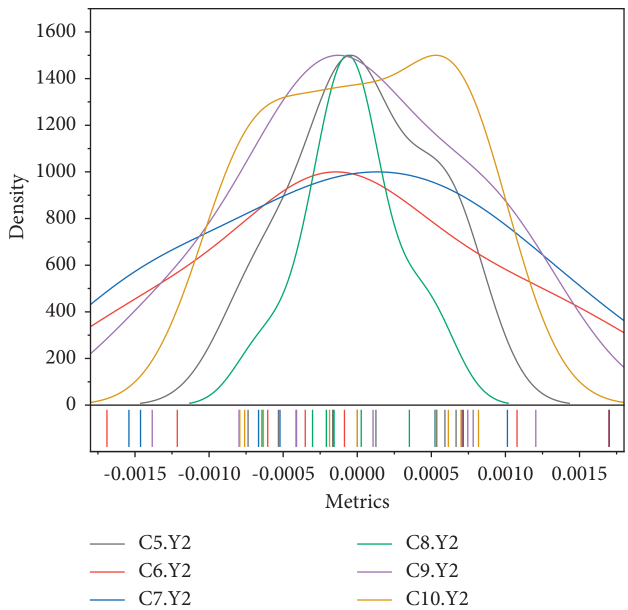

FIGURE 8: Average accuracy metrics measurement.

smooth interaction with the work, realizes the natural integration of subject, object, and surrounding environment, and then forms the real immersion experience and the final emotional transmission.

5. Conclusion

In this paper, an intelligent classification algorithm for Chinese painting painters based on a multibranch attention mechanism network is proposed from multifeature fusion and deep semantic representation of features. Firstly, the algorithm uses contrast statistical features to eliminate digital Chinese painting image blocks with little information; secondly, the features are pregenerated for digital Chinese paintings using the style characteristics of Chinese paintings; then, an intelligent classification network based on multibranch attention mechanism is designed to complete the fusion and classification of Chinese painting features.

Based on the analysis of the innate advantages of AI technology, this study proposes how AI can change the original paradigm of interactive art expression application from the level of creative thinking, creation mode, and art experience so as to establish an intelligent interactive art creation model in the context of AI. Based on the study of interactive art expression form under the influence of AI technology, it proposes that AI changes the original concept of art aesthetics from space, time, and natural logic. Based on the study of interactive art expressions under the influence of AI technology, we propose the changes of AI on the original concept of art aesthetics in terms of space, time, and natural logic and analyze its aesthetic characteristics of debounddaryization, immersion, and emotionality. This paper focuses on the deconstruction and reconstruction of interactive art expression by artificial intelligence. This paper proposes a digital Chinese painting authenticity-assisted authentication method based on twin networks. Firstly, we use adversarial generative networks to learn the characteristics of painters' paintings and generate corresponding painters' forgeries; secondly, we propose a deep learning-based digital Chinese painting authenticity-assisted identification network for the generated forgeries; then, we visualize the characteristic regions of painters' images; finally, we develop an authenticity-assisted identification system based on the web, which can produce more accurate-assisted identification results and provide experts with an objective basis for experts. Through experimental analysis, it is proved that the proposed method has good sensitivity to digital forgeries and is scalable.

In the future, the brushstroke feature map processed by the edge detection algorithm can quantify the painter's artistic style by detecting the edge contours of the painter's brushwork. In addition, after a large amount of data collection, we may encounter the problem of big data analysis. At this time, we will use some lightweight optimization models to solve the problem of big data analysis. In the near future, we will further use artificial intelligence methods to learn and simulate the artistry of painters so as to realize the ability of automatic painting of artificial intelligence.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

English Machine Translation Model Based on an Improved Self-Attention Technology

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English machine translation is a natural language processing research direction that has important scientific research value and practical value in the current artificial intelligence boom. The variability of language, the limited ability to express semantic information, and the lack of parallel corpus resources all limit the usefulness and popularity of English machine translation in practical applications. The self-attention mechanism has received a lot of attention in English machine translation tasks because of its highly parallelizable computing ability, which reduces the model's training time and allows it to capture the semantic relevance of all words in the context. The efficiency of the self-attention mechanism, however, differs from that of recurrent neural networks because it ignores the position and structure information between context words. The English machine translation model based on the self-attention mechanism uses sine and cosine position coding to represent the absolute position information of words in order to enable the model to use position information between words. This method, on the other hand, can reflect relative distance but does not provide directionality. As a result, a new model of English machine translation is proposed, which is based on the logarithmic position representation method and the self-attention mechanism. This model retains the distance and directional information between words, as well as the efficiency of the self-attention mechanism. Experiments show that the nonstrict phrase extraction method can effectively extract phrase translation pairs from the n-best word alignment results and that the extraction constraint strategy can improve translation quality even further. Nonstrict phrase extraction methods and n-best alignment results can significantly improve the quality of translation translations when compared to traditional phrase extraction methods based on single alignment.

1. Introduction

After decades of development and evolution in English machine translation, with the continuous improvement of information technology and computer technology, the research on English machine translation has gradually evolved from the original simple linguistics and computational sciences [1, 2]. It transforms into a comprehensive research field that integrates semantics, mathematics, corpus, computing science, artificial intelligence, and biological sciences. However, the translation quality of English machine translation still cannot reach the level people expect [3]. Especially on the problem of long sentence processing, although computer and other related sciences have made a qualitative leap compared with more than ten years ago, the problem of long sentence processing is still an insurmountable obstacle in the field of English machine translation research [4–6]. It is difficult for long sentences to have a unified and accurate definition because of their different fields and applications. Compared with English machine translation, manual translation is easier to combine the comprehensive background, understand its semantic information, and select the most suitable target language. Translation system capabilities also include other elements such as bilingual knowledge representation, cultural knowledge, and physiological and psychological factors. At present, English machine translation has not reached the level of fully intelligent understanding of semantic information, and it is necessary to continuously give computers the ability to recognize and understand [7, 8].

Because the traditional manual translation method is far from meeting the market requirements due to its high cost and slow translation speed, English machine translation came into being in line with the trend of the times [9]. The development of English machine translation technology has been closely following the development of information science, linguistics, and computer science. It is the crown jewel in the field of natural language processing and an important breakthrough and milestone in the field of artificial intelligence. The survey shows that skilled and experienced human translators can complete about 2000 words per 8 hours [10]. This kind of work efficiency cannot meet the growing demand for translation. However, the total amount and speed of translation that an English machine translation system can complete are thousands of times that of human translation [11, 12]. In actual work, English machine translation can shorten delivery time and greatly increase work efficiency. In addition, the translation industry has very high requirements for the professional quality of translators. For some small languages and dialects, there is a shortage of relevant talents. With the help of English machine translation, the translation quality can meet the basic task requirements to make up for the lack of good and bad translators [13–15]. When the number of translations is small, the difference between the cost of manual translation and English machine translation is not particularly obvious. When the workload of translation is increased, the cost of manual translation is much higher than the cost of English machine translation. It takes a very long time and consumes a lot of manpower to train a small language talent with professional knowledge reserves [16].

In order to improve the performance of English machine translation, this paper combines the log position representation with the SA mechanism. Specifically, the technical contributions of this article are summarized as follows.

First, the model proposed in this paper can achieve better scores in tasks with many long sentences, but the effect is not particularly ideal in tasks with many short sentences. This is because when using logarithms to take relative position expression subscripts, for short sentences, the accuracy between short-distance words is not high enough, and for long sentences, the log function converges slowly and blurs the long-distance in a gradual manner. You can capture the difference in the positional relationship between long-distance words.

Second, experiments were carried out for single alignment and N-best alignment. The experimental results show that the nonstrict phrase extraction method is better than the traditional method in the two cases, and the BLEU score has been further improved after the extraction constraint strategy is applied.

Third, this article compares the effects of different extraction constraint strategies on the final translation results in detail. Experiments show that the nonstrict phrase extraction method is more suitable for extracting phrases on the N-best alignment, and imposing extraction constraints can further improve the translation quality.

2. Related Work

In recent years, with the development of deep learning (DL), people have gradually begun to introduce deep learning to train a multilayer neural network to complete predetermined tasks [17]. In the field of natural language processing, such as English machine translation, question answering system, and reading comprehension, certain successes have been achieved [18]. The neural machine translation (NMT) system introduces deep learning technology; one of the mainstream technologies is to still retain the framework of statistical English machine translation, but to improve certain intermediate modules through deep learning technology, such as translation models, language models, and order adjustments [19]. Another type of method is to no longer use statistical English machine translation as the framework (no preprocessing such as word alignment is no longer needed, and no human design features are needed), but the end-to-end NMT system framework is proposed by related scholars [20].

Generative adversarial network (GAN) is a generative model. The basic idea of GAN is inspired by game theory. First, they get a lot of training samples from the training library, then learn these training cases, and finally generate a probability distribution [21]. The two sides of the game in the GAN model are composed of generative model (GM) and discriminative model (DM). GM captures the distribution of sample data. It is a two-classifier used to estimate the probability that a sample comes from training data. GAN has the potential to generate "infinite" new samples in a distributed manner and has great application value in the fields of artificial intelligence, such as image, visual computing, and voice processing [22, 23]. GAN provides a new direction for unsupervised learning and provides methods and ideas for processing high-dimensional data and complex probability distributions.

There are a few initial applications of GAN in the field of natural language processing, mainly because the initial design of GAN requires that both the generation model G and the discriminant model D deal with continuous data. GAN can be changed by the minor parameters of the GM model. The difference between natural language processing and image processing is that the value of the image is continuous, and small changes can be reflected in the pixels, while in the text sequence, the GM generated data is discrete, and the information given by the corresponding DM is meaningless [24]. In other words, natural language processing is a discrete sequence, GM needs the gradient obtained from DM for training, and the BP algorithm of neural network cannot provide gradient value for GM.

Related scholars provide a seed sentence segmentation method for the tree-based English machine translation system [25]. This method first divides the long sentence into shorter clauses, translates the clauses, and merges the subtranslations to generate the full sentence translation. This method analyzes the syntax tree generated by the existing syntax analyzer to realize the segmentation of long sentences and the merging of translations. However, the correctness of the syntax tree is difficult to guarantee. If there is an error in the syntax tree, analysis of the wrong tree will result in error accumulation.

Researchers designed and implemented a long sentence processing subsystem [26]. Based on the study of the laws of linguistics, this paper proposes a seven-layer model diagram of the relationship between language units and translation units and proposes a long sentence analysis scheme based on this [27]. The plan first segmented and simplified the long sentence based on linguistic knowledge and used the existing system IMT/EC translation mechanism to translate the clauses one by one; finally, by analyzing the relationship between the clause translations, the subtranslations were merged to obtain the translation of the entire long sentence. The method of this article not only considers the structural characteristics of the long sentence but also considers the grammatical and semantic characteristics of the clauses in the long sentence. However, the segmentation of long sentences only uses limited features such as punctuation and keywords.

Relevant scholars have proposed that pattern rules can be used to analyze parameterized text, and pattern rules and parameterized text free grammar are treated separately [28]. Some syntactic and semantic functions are used to parameterize the free grammar of the text. The pattern rules and the free grammar of the parameterized text are in a complementary relationship, so that the long English sentences represented by the patterns can be effectively analyzed. The problems of this method are mainly focused on sentence components such as prepositional phrases and compound noun phrases. Many segmentation points are wrong because it disconnects these phrases [29, 30].

3. Method

3.1. Position Coding. There is no recursive layer and convolutional layer in the transformer model. Therefore, in order to enable the model to use the position information in the input sequence, the sine and cosine position coding method and the SA mechanism in the Transformer are combined for application. This position coding method uses the sin function and the cos function performs position coding. Its advantage is that the sequence length of the model can be extended. It is essentially an absolute position information coding method. Moreover, the residual connections used around each sublayer also help to transfer location information to higher layers. The calculation method of sine and cosine position coding is as follows:

$$PE_{(\mathrm{pos},2i)} = \sin\left(\frac{\mathrm{pos}}{10000^{2i/d}}\right)\cdot \cos\left(\frac{\mathrm{pos}}{100^{4i/d}}\right). \quad (1)$$

$$PE_{(\mathrm{pos},2i|-1)} = \sin\left(\frac{\mathrm{pos}}{200^{3i/d}}\right)\cdot \cos\left(\frac{\mathrm{pos}}{1000^{3i/4d}}\right). \quad (2)$$

Here, pos represents the input position and i represents the dimension; that is, each dimension of the position code has a corresponding sine and cosine function, where formula (1) represents the position code representation of even-numbered dimensions and formula (2) represents the position coded representation of the dimension.

Although the position coded representation obtained in this way can reflect the relative distance between words, it lacks directionality, and this position information will be destroyed by the attention mechanism in transformer. Therefore, this paper proposes a new position representation method-logarithmic position representation and combines it with the SA mechanism, so that the model can not only effectively use the advantages of the SA mechanism parallel computing but also accurately capture the words between words.

The RNN mechanism and SA mechanism are shown in Figure 1. In RNN, although the word encoding of the two words is the same, the state of the hidden layer used to generate the two words is different. For the first word, the hidden state is the initialized state; for the second word, the hidden state is the hidden state that encodes two words. It can be seen that the hidden state mechanism in RNN ensures that the output representation of the same word in different positions is different.

In self-attention, the output of the same word is exactly the same, because the input used to generate the output is exactly the same. This will cause the output representations of the same words at different positions in the same input sequence to be completely consistent, which will not reflect the timing relationship between the words. Therefore, relative position representation (RPR) was proposed. RPR adds a trainable embedding code to the self-attention model, so that the output representation can reflect the timing information of the input. These embedding vectors are used to calculate the attention weight and value between any two words *xi* and *xj* in the input sequence. Time was added to it. This embedding vector represents the distance between words *xi* and *xj*.

3.2. Self-Attention Mechanism. The SA mechanism has parallel computing capabilities and modeling flexibility. The multihead attention (MHA) mechanism in the SA mechanism can enable the model to pay attention to the corresponding information from different subspaces. The SA mechanism ignores the position factor of the word in the sentence, and it can explicitly capture the semantic relationship between the current word and all words in the sentence. The MHA mechanism maps the input sequence to different subspaces. These subspaces use the SA mechanism to further enhance the performance of the English machine translation model. The advantages of the SA mechanism are as follows:

(1) There are fewer parameters. Compared with the traditional LSTM model, the SA mechanism has less complexity and fewer parameters, so the requirements for computing power are also lower. (2) It has faster speed. The calculation result of each step of the SA mechanism does not depend on the calculation result of the previous step, which solves the problem that RNN cannot be trained in parallel. (3) It has better effect. The SA mechanism can capture the semantic relationship between global words and effectively solve the problem of weakened long-distance information in RNN.

When using the SA mechanism to process each word (i.e., each element in the input sequence), such as when

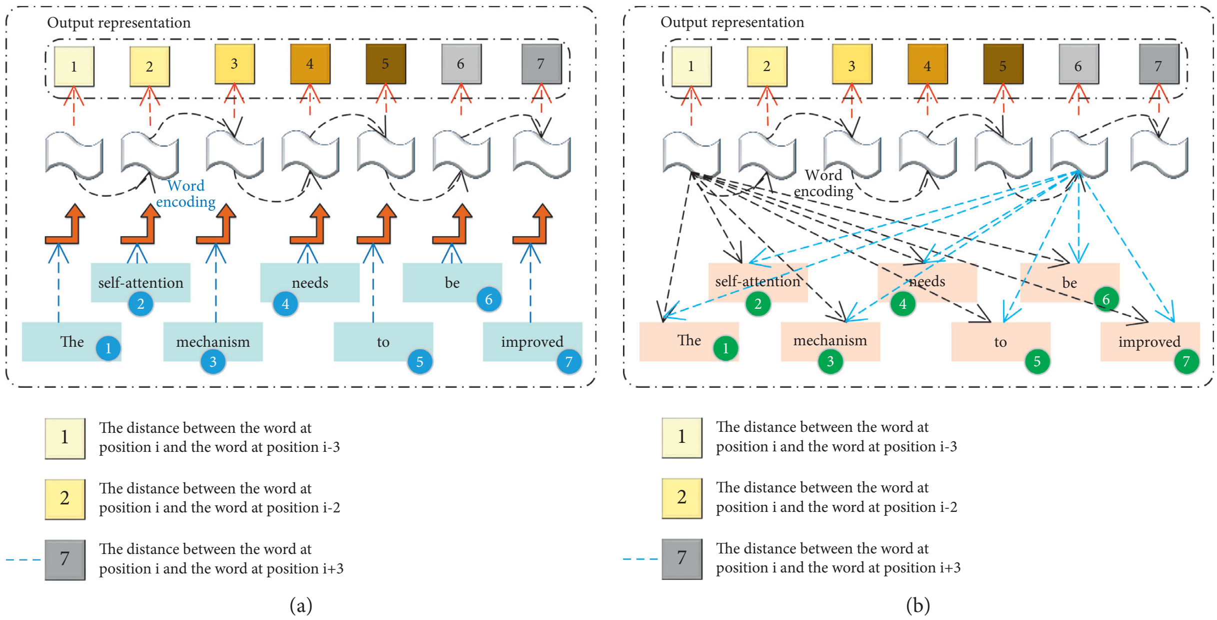

Figure 1: Comparison of RNN mechanism and SA mechanism: (a) RNN and (b) SA.

calculating *xi*, the SA mechanism can associate it with all words in the sequence and calculate the semantic similarity between them. The advantage of this is that it can help to mine the semantic relationship between all words in the sequence, so as to encode the words more accurately.

For the element *zi* in the output sequence Z, the input elements *xi* and *xj* are linearly transformed and their weighted sum is calculated:

$$z_i = \prod_{j=0}^{n-1} \text{soft max}\left[K_{j,T} V_j Q_i d_k^{-1/2}\right]. \tag{3}$$

In the Softmax function, the linear transformation of the input elements enhances the expression ability. The Softmax score determines the size of the attention score expressed by each word at the current position. Here, multiplying the value vector *Vj* by the Softmax score is to maintain the integrity of the value of the currently focused word and to overwhelm irrelevant words. Then, these weighted value vectors are summed to get the SA output, which will be sent to the feedforward neural network layer for further calculations. The calculation of the Softmax function is as follows:

$$\text{soft max}\left(a_{ij}\right) = \exp\left(a_{ij}\right) \cdot \prod_{k=0}^{n-1} \exp\left(a_{ik}^{-1}\right). \tag{4}$$

Q, K, and V represent query, key, and value, respectively, which are abstract representations useful for calculating attention scores, and dk is the dimension of key.

The SA mechanism uses l attention heads, and the outputs of all attention heads are combined, and then linear transformation is performed to obtain the output of each sublayer. The multihead attention mechanism expands the model's ability to focus on different positions. For example, if you want to translate "Tom did not come to work because he was ill," you need to know what "he" refers to. The multihead attention mechanism is suitable for such situations. The multihead attention mechanism provides multiple representation subspaces for the attention layer. The multihead attention mechanism provides multiple sets of Query, Key, and Value. These sets are randomly initialized and generated. After training, each set will be used. The embedding for the input is then put into different representation subspaces. The calculation formula for the output result of the multihead attention mechanism is as follows:

$$\text{multihead}\,(Z) = \text{Concat}\left(W^0 \quad z_{\text{head}1} \quad \cdots \quad z_{\text{head}i}\right). \tag{5}$$

z_{headi} represents the output vector of the ith attention head. The function of Concat () is to merge the output vectors of all attention heads. W_O is the weight matrix generated during model training. As shown in Figure 2, the multihead attention mechanism combines the output of each attention head and then performs a linear transformation to obtain the final output.

3.3. Improved English Machine Translation Model Construction. In this paper, a new model of English machine translation based on logarithmic position representation and self-attention mechanism is proposed. As shown in Figure 3, the model has 7 encoders and 7 decoders as well as an output layer. Attention combined with logarithmic position representation layer and fully connected FFN network layer. In the decoder, there are self-attention combined with logarithmic position representation layer, encoder-decoder attention layer, and fully connected FFN network layer. The output layer contains the linear transformation layer and the Softmax fully connected layer.

Because there are no RNN and CNN in the SA mechanism, the sequence information in the text will be ignored.

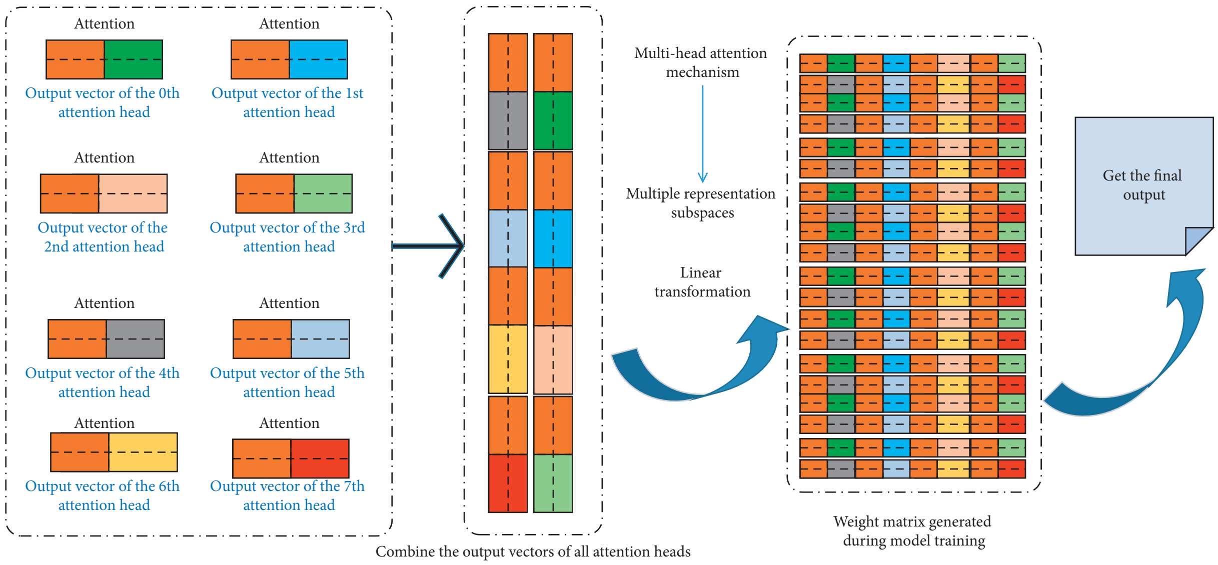

Figure 2: Multihead attention mechanism.

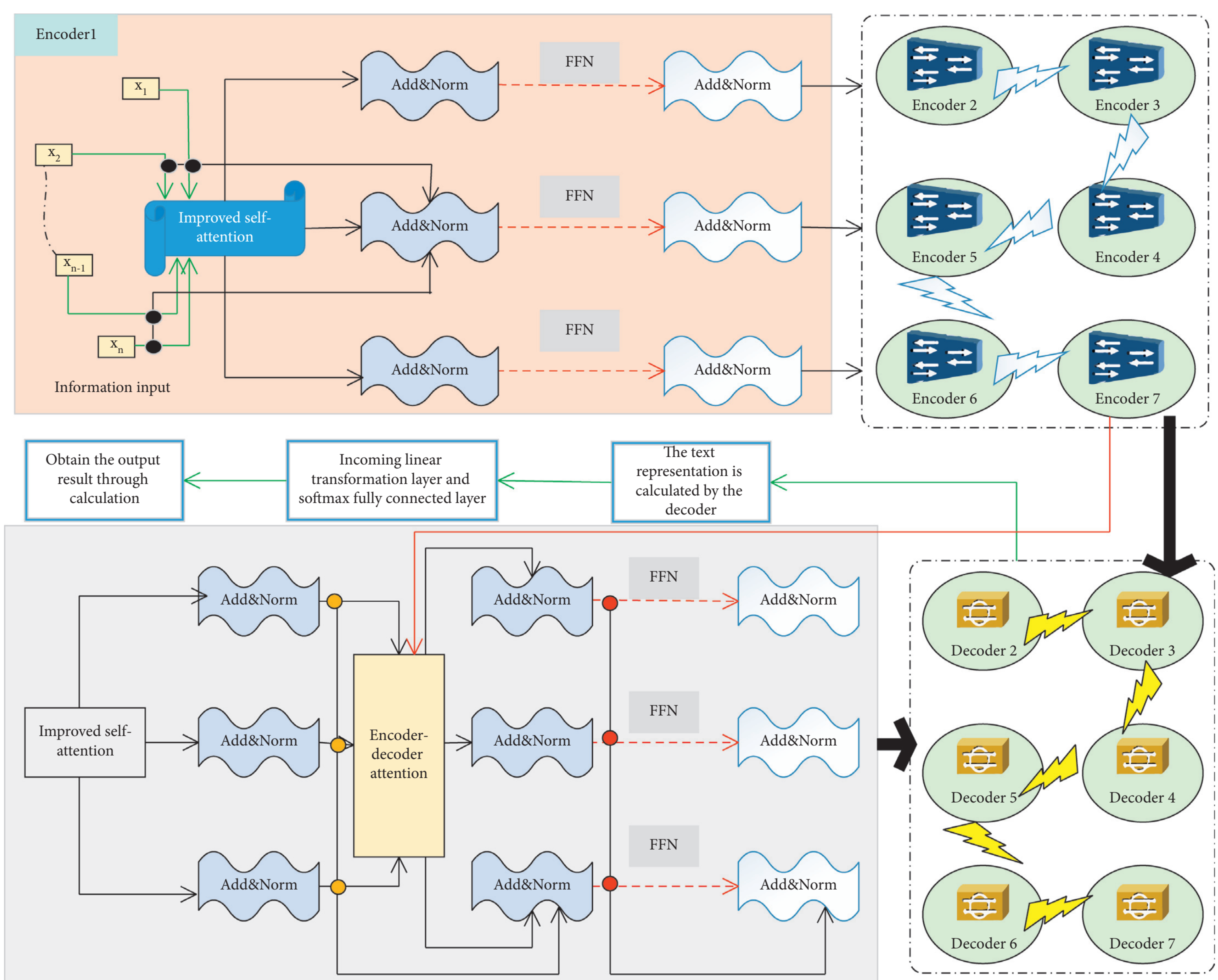

Figure 3: English machine translation model based on logarithmic position representation and self-attention.

In order to make full use of the sequence information, a method is proposed in the article extracting the position information of the input element $xi \in X = (x1, \ldots, xi)$; the position information proposed in this paper essentially represents the relative positional relationship between the input elements xi and xj. I construct these input elements as a directed complete graph with xi $(i = 1, 2, \ldots, n)$ as nodes and eij as edges, and eij contains the relative positional relationship between xi and xj.

In this paper, the vector LP is used to represent the logarithmic positional relationship between the input elements xi and xj. The logarithmic position relationship is added to the model, and the following formula is obtained:

$$z_i = \prod_{j=0}^{n-1} \text{soft max}\left[\left(LV_j Q_i + P_{ij,v} K_j\right) \cdot \left(d_k^{-1/2} V_j Q_i + LP_{ij,k} K_j\right)^{-1}\right]. \tag{6}$$

The injection of position information can greatly improve the situation where the encoder in the SA mechanism ignores the hierarchical structure of the input sequence. In specific tasks such as English machine translation, natural language inference, and intelligent question answering systems, location information plays an extremely important role.

4. Results and Discussion

4.1. Translation Effect on Single Word Alignment. I compared the final translation quality between nonstrict phrase extraction and strict phrase extraction when no extraction constraints were added. Table 1 shows the BLEU scores when using various word alignment and recombination methods for strict phrase extraction.

It can be seen from Table 1 that different alignment and recombination methods have a greater impact on the BLEU score of the final translation result. The grow-diag-final method has the highest BLEU score; the grow method has the lowest BLEU score. At the same time, it can be seen from the table that the method of adding the alignment points to the diagonal during the alignment and reorganization process (grow-diag, grow-diag-final, grow-diag-final-and, and union) is obviously better. The method of aligning points to the diagonal (grow, intersect), which shows that the aligning points on the diagonal are useful for phrase extraction. Corresponding to the word alignment of bilingual sentences, it is that most of the word sequences in the sentence tend to be strictly monotonous if the previous word in the source language sentence word sequence corresponds to the previous word in the target language sentence word sequence; then, the next word in the word sequence also tends to correspond to the next word in the word sequence of the target language sentence. In our experiment, the result of the grow method is not as good as the intersect method, which shows that adding horizontal or vertical alignment points in the alignment, and reorganization process is generally useless. Table 2 shows the BLEU scores of nonstrict phrase extraction using various word alignment and recombination methods.

Table 1: BLEU scores for strict phrase extraction in a single alignment.

Alignment and reorganization method	BLEU score
Union	0.39
Intersect	0.3
Grow	0.29
Grow-diag	0.35
Grow-diag-final	0.42

Table 2: BLEU scores for nonstrict phrase extraction in a single alignment.

Alignment and reorganization method	BLEU score
Union	0.43
Intersect	0.31
Grow	0.32
Grow-diag	0.36
Grow-diag-final	0.43

It can be seen from Table 2 that the BLEU score of nonstrict phrase extraction is generally better than that of strict phrase extraction (obviously, the intersect results of the two are the same). In nonstrict phrase extraction, the impact of different alignment and recombination methods on the final translation result BLEU score is also different from that in strict phrase extraction: the BLEU score of the union method exceeds that of the grow-diag-final method. Looking at the BLEU score from highest to bottom (union > grow-diag-final > grow-diag-final-and > grow-diag > grow > intersect), the alignment result contains the BLEU score of the alignment reorganization method with more alignment points, which is different from the situation in strict phrase extraction. This shows that in nonstrict phrase extraction, the coverage rate of alignment points has a greater impact on the final result than the accuracy rate. Because the nonstrict phrase extraction itself has a certain antinoise ability, it reduces the requirements for word alignment accuracy and does not require a very complicated alignment and recombination method.

On the whole, the extraction constraint strategy can effectively improve the BLEU score. The method based on vocabulary similarity is better than the method based on the intersection of alignment points. The improved self-attention constraint is based on the maximum likelihood under the condition of the alignment point. The comparison method has the highest BLEU score under the union word alignment and reorganization. Among all the methods based on vocabulary similarity, the method based on improved self-attention is less effective. Even under the condition of union and grow-diag-final word alignment and recombination, the BLEU score is worse than the method based on the intersection of alignment points. There is not much improvement effect; the method based on PHI square coefficient has better BLEU scores under various word alignment and recombination conditions; the method based on log-likelihood ratio is BLEU under the conditions of union, grow, and grow-diag word alignment and

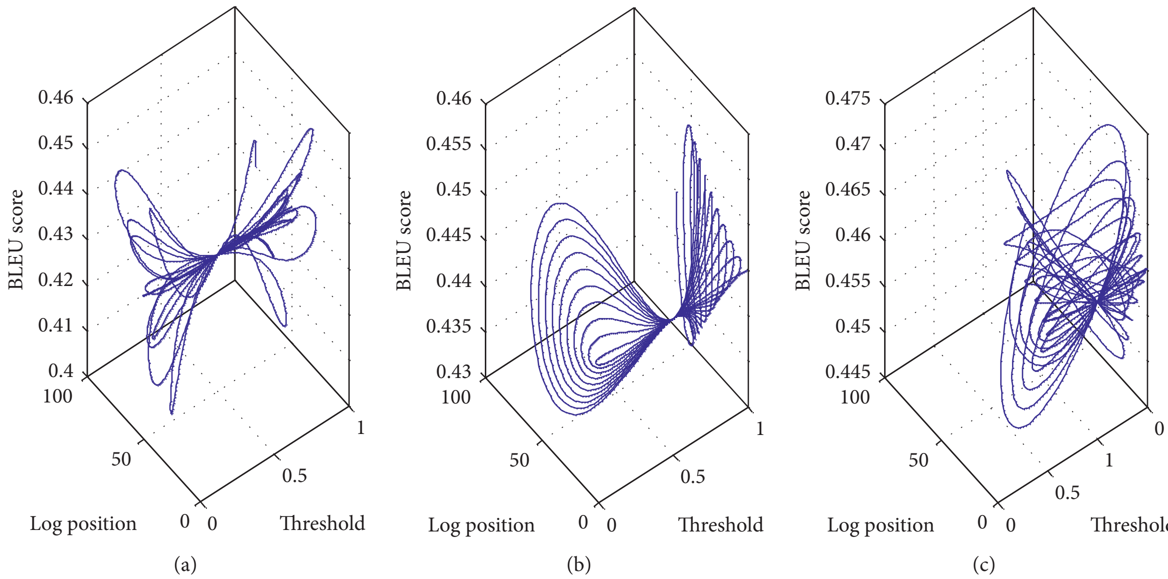

Figure 4: The relationship between BLEU and threshold under the constraints of improved self-attention method for single alignment: (a) constraints are not based on alignment points, (b) constraints are based on alignment points, and (c) improved self-attention constraints are based on alignment points.

recombination. The score is better, but the BLEU score under the conditions of grow-diag-final and grow-diag-final-and word alignment and recombination has a large drop, which shows that the log-likelihood ratio constraint is too strict. In these two types of methods, final and final-and processes may include alignment points that are not deterministic alignments, but the log-likelihood ratio constraint regards these alignment points as must be included in phrase extraction. However, the log-likelihood ratio has a better ability to constrain too broad results like union word alignment and recombination.

In Figure 4, the influence of threshold changes in the constraint extraction strategy based on improved self-attention on the BLEU score of the final translation is shown. From this, we can see that the threshold change has a greater impact on the BLEU score of the final translation result, indicating that the improved self-attention constraint has a greater impact on phrase extraction, which means that this method can form an effective constraint.

4.2. Translation Effect on n-Best Word Alignment. We take the best alignment numbers as 10, 20, 30, 40, and 50, respectively, for the translation experiment on n-best alignment. We still compare the final translation quality of nonstrict phrase extraction and strict phrase extraction without adding extraction constraints. The BLEU scores of strict phrase extraction using various word alignment and recombination methods are shown in Table 3. Here, the best result on n-best is selected for each word alignment.

In the alignment and reorganization method, the result of n-best is not as good as the result of single alignment. This is mainly because these alignment and reorganization methods cover more alignment points on the n-best alignment, and strict phrase extraction can only perform phrase extraction based on the outermost boundary of the alignment, so it is more severely affected by noise. There are certain improvements in other alignment and reorganization methods, mainly because these methods cover fewer alignment points on a single alignment, and many useful alignment points are recalled after being expanded to n-best. However, from a general point of view, the highest BLEU score of strict phrase extraction on the n-best alignment results is still lower than that of a single alignment, indicating that strict phrase extraction is not suitable for the n-best alignment and reorganization used in this article.

Table 3: BLEU scores for strict phrase extraction in n-best alignment.

Alignment and reorganization method	BLEU
Grow-diag-final-and	0.39
Grow-diag-final	0.41
Grow-diag	0.37
Grow	0.33
Intersect	0.31
Union	0.25

Figure 5 shows the variation of strict phrase extraction with n-best alignment. It can be seen that for all alignment and recombination methods, the BLEU score fluctuates with the increase of n-best alignment, which shows that the strict phrase extraction method can improve the effectiveness of extraction as the alignment number increases.

Table 4 shows the BLEU scores of various word alignment and recombination methods used in nonstrict phrase extraction without extraction constraints. It can be seen that in all word alignment and recombination methods, nonstrict

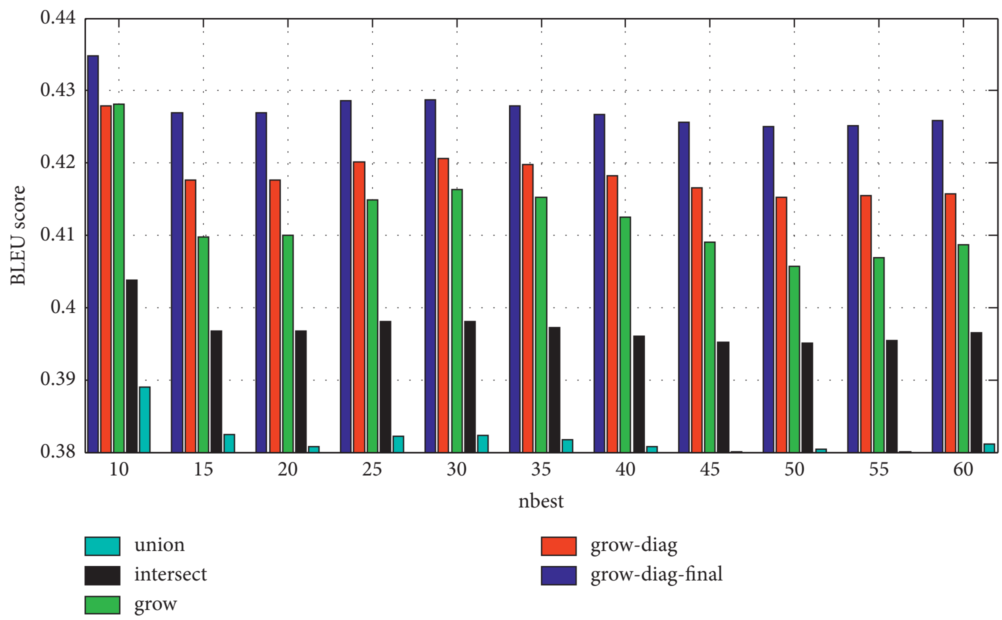

Figure 5: The BLEU score of the simple superposition of n-best alignment results in strict phrase extraction.

Table 4: BLEU scores for nonstrict phrase extraction in n-best alignment.

Alignment and reorganization method	BLEU
Grow-diag-final-and	0.40
Grow-diag-final	0.42
Grow-diag	0.36
Grow	0.34
Intersect	0.32
Union	0.26

phrase extraction improves the BLEU score on n-best than on single alignment. This shows that the n-best alignment recombination method mentioned in this article is suitable for nonstrict phrase extraction.

Figure 6 further shows the variation of nonstrict phrase extraction with n-best alignment. It can be seen that for most alignment and recombination methods, the BLEU score does not change much with the number of n-best alignments. Therefore, simply using the nonstrict phrase extraction method cannot improve the effectiveness of the extraction with the increase of the number of alignments, but it will not significantly reduce the effectiveness. It is also worth noting that in terms of n-best alignment, the grow-diag-final method is better than the union method. This may be due to the introduction of too many alignment points in the union method, which reduces the effectiveness of phrase extraction.

Figure 7 shows the relationship between the BLEU score and the n-best alignment under the constraints of the improved self-attention alignment point intersection method. When the number of n-best alignments increases, the BLEU score is not less than 0.445, which shows that the method based on the intersection of alignment points is effective in n-best alignment.

Figure 8 shows the relationship between the BLEU score and the threshold under the improved self-attention constraint in n-best alignment. It can be seen from the figure that for improved self-attention, there is still a difference whether the alignment point has been aligned under n-best alignment. When the threshold is increased, the improved self-attention constraint is relatively maximum based on the BLEU score of the alignment point.

The effect is best when the constraint is based on the existing alignment, the effect is worse when the constraint is strictly based on the existing alignment, and the effect is the worst when the constraint is not based on the existing alignment. Because the log-likelihood method has strong constraints, when there are many alignment points, the constraints strictly based on the existing alignment are too strict, so it becomes worse. The constraints are not strictly based on the existing alignment. The constraints are looser, and the effect is better. When the alignment is not based on the existing alignment, the alignment points other than the existing alignment can be used as constraints, which is equivalent to strengthening the constraints, and the effect is not good. As the threshold increases, the constraint relaxes, and the BLEU score increases strictly according to the existing alignment method, indicating that this restriction is too strict for n-best alignment; the BLEU score that does not strictly follow the existing alignment method increases first, indicating that the degree of restriction is moderate, and only when the threshold is relatively large will it show a downward trend; the BLEU score basically declines without the existing alignment method, and its effect is not as good as the previous two.

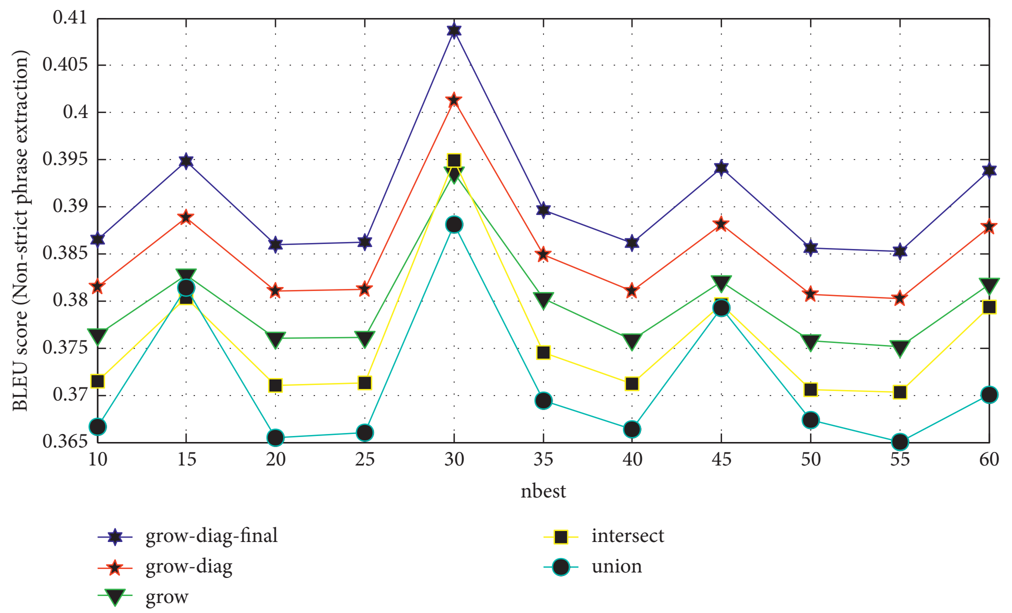

FIGURE 6: BLEU score of simple superposition of n-best alignment results in nonstrict phrase extraction.

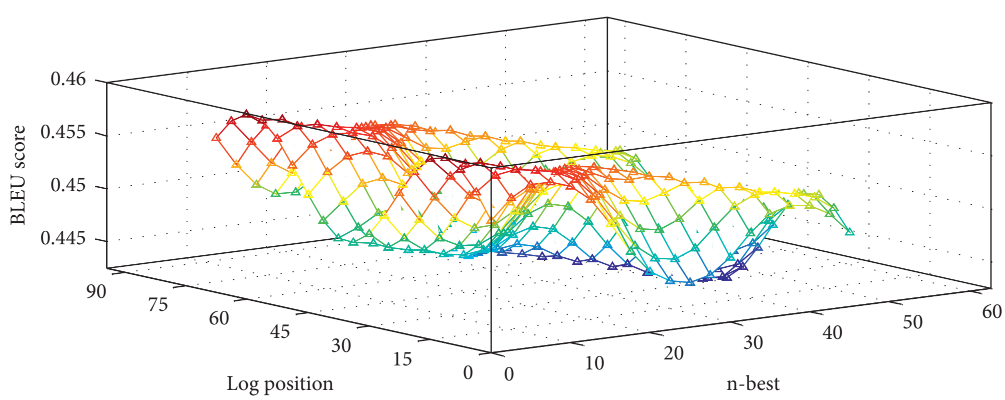

FIGURE 7: The relationship between BLEU and n-best alignment under the constraint of the improved self-attention alignment point intersection method.

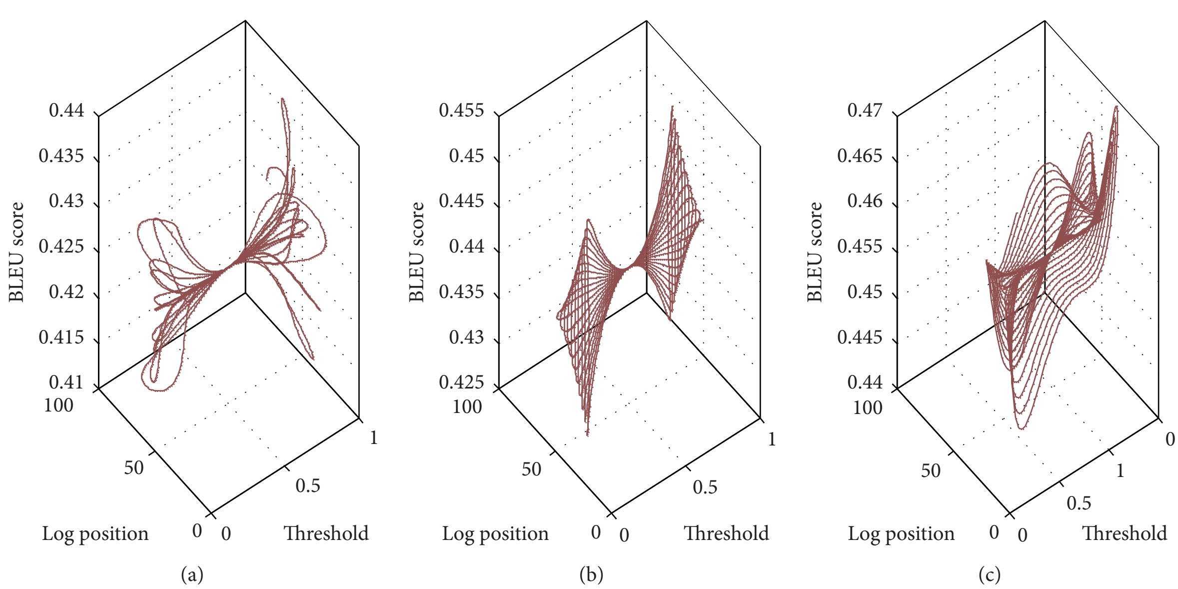

FIGURE 8: The constraint of n-best alignment in the improved self-attention is based on the BLEU score under the alignment point. (a) Constraints are not based on alignment points, (b) constraints are based on alignment points, and (c) improved self-attention constraints are based on alignment points.

5. Conclusion

This article analyzes the self-attention mechanism ignoring word order structure. Aiming at the problem of not being able to capture the position information of the words in the sentence, the analysis shows that the position of the words in the sentence is very important feature information. It plays an important role in guiding reference disambiguation and semantic analysis. For this problem, this paper proposes a new English machine translation model based on logarithmic position representation and self-attention. This model further enhances the model's ability to capture word position information by adding logarithmic position representation in the self-attention layer. This performance enhancement is not only reflected in distance but also in directionality. The logarithmic representation method blurs the concept of "long distance" and makes the relative position representation free from the "window." The experimental results show that the model proposed in the article has better performance than the traditional recurrent neural network English machine translation model and the traditional self-attention English machine translation model in English-to-German and English-to-French English machine translation tasks. This article proposes the idea of using n-best alignment results for phrase extraction. In order to effectively extract phrases from n-best alignment results, a nonstrict phrase extraction method is proposed, focusing on the impact of various extraction constraint strategies in nonstrict phrase extraction methods on the quality of the final translation, mainly including alignment points. Compared with the traditional strict phrase extraction method, the final translation quality of nonstrict phrase extraction in both single alignment and *n*-best alignment is improved, and it is more suitable for extracting phrases from *n*-best alignment effectively. However, the error recognition rule base needs to be improved. The error-driven long sentence segmentation method formulates error identification and correction strategies by summarizing the errors in the segmentation results. Fundamentally speaking, these strategies belong to the category of rules. In the future, we will consider formulating a more standardized and complete knowledge representation form to accurately represent each linguistic feature, so as to promote the application of the method.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Research on the Identification and Evaluation of Aerobics Movements Based on Deep Learning

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A deep learning approach is used in this study to provide insight into aerobics movement recognition, and the model is used for aerobics movement recognition. The model complexity is significantly reduced, while the multi-scale features of the target at the fine-grained level are extracted, significantly improving the characterization of the target, by embedding lightweight multi-scale convolution modules in 3D convolutional residual networks to increase the local perceptual field range in each layer of the network. Finally, using the channel attention mechanism, the key features are extracted from the multi-scale features. To create a dual-speed frame rate detection model, the fast-slow combination idea is fused into a 3D convolutional network. To obtain spatial semantic information and motion information in the video, the model uses different frame rates, and the two-channel information is fused with features using lateral concatenation. Following the acquisition of all features, the features are fed into a temporal detection network to identify temporal actions and to design a behavior recognition system for the network model to demonstrate the network model's applicability. The average scores of students in the experimental group were significantly higher than those in the control group in seven areas: set accuracy, movement amplitude, movement strength, body co-ordination, coordination of movement and music, movement expression, and aesthetics; the average scores of movement proficiency and body control in the experimental group were also significantly higher than those in the control group, but the differences were not significant. The differences between the eight indicators in the experimental group were not significant when compared to those in the preexperimental group, indicating that intensive rhythm training for students improves secondary school students' comprehension, proficiency, and presentation of aerobics sets.

1. Introduction

After the development of aerobics as an international competition, the competition structure has been continuously differentiated, and trying to highlight the competitive characteristics, the rules as the project development of the wind vane, is the best embodiment of the project competitive characteristics. There is a new interpretation of the assessment of the athletes' participation in the sets, and the excellent results not only rely on high technical ability but also require the all-around development of athletic ability, especially the need to have excellent physical fitness [1]. Although aerobics is a skill-driven event group, strong physical fitness is essential to complete the high standard of the competition within the stipulated competition time. Good physical fitness not only can drive the improvement of skills, but also is a necessary condition to complete the competition goals and improve the competition results; excellent strength quality is to achieve the guarantee of solid improvement of difficult techniques, superendurance quality helps the competition in high-quality play, and the combination of movement and fast and powerful movements helps to improve the artistic score. In aerobics, as in diving, competitive gymnastics, wushu, and other sports, the judges assess the athletes' performance subjectively according to the scoring rules [2]. The control group adopts the traditional aerobics teaching methods. Teachers pay more attention to the training of various technical movement specifications and routines of aerobics when teaching. Music is an indispensable part of aerobics. At present, for athletes in such sports, the identification of their athletic ability and athletic rating is often based on the results achieved by the athletes in various competitions. This is inevitably influenced by the size of the competition and the level of the participants. Therefore, it is very meaningful to establish a set assessment system for athletes' specific athletic competitive abilities in these sports. With this assessment system, coaches can use a unified quantitative standard to assess the level of athletic ability development of athletes, to tailor the training content, method, intensity, and density for each athlete more precisely and effectively, so that each athlete can obtain the optimal training effect.

However, most of them only point out which physical fitness indicators have a more significant effect on sports performance and abstractly conclude that coaches should strengthen this aspect more in training, without giving specific quantitative indicators, which is insufficient for our coaches. Modern training programs must move towards quantification and precision, which urgently requires an assessment model of the relationship between physical fitness indicators and athletic performance [3]. With the assessment model, each training has a clear target and provides a scientific basis for the daily training arrangement. In the past, some scholars have used the multiple regression method to establish the assessment model of some sports, but the factors affecting the competitive ability of special sports not only have their functional characteristics but also make up for each other and promote and influence each other, forming a complex dynamic quality system in the human body, so their influence on the final level is often not linear. The method of multiple regression establishes a model that is a linear equation, which necessarily cannot simulate the changing relationship between indicators and performance very accurately [4]. Athletes not only need to have the ability to complete complex and diverse actions with high quality, but also need to realize the seamless integration of action content and musical rhythm. Such competition needs require higher coordination and sensitivity, spatial conversion, and perception capabilities of athletes. Therefore, it is urgent to build an assessment model with a higher degree of simulation. Somatosensory technology is the best embodiment of human action recognition in human-computer interaction. Before the advent of somatosensory technology, human-computer interaction used hardware devices, such as mouse and keyboard, to manipulate the computer, reducing the freedom of human-computer interaction. The advent of somatosensory technology allows people to use their body movements very directly to manipulate the surrounding settings or to interact with the environment around them. Somatosensory technology allows people to get rid of the control of hardware facilities such as keyboards and mice and interact with computers more directly and freely, allowing people to integrate more realistically into the environment of human-computer interaction [5].

However, special theoretical research mainly concentrated in a few major areas, and there are still many important areas that have not been covered. Theoretical research lags a little behind compared with practice, which is bound to become an obstacle for the continued development of aerobics. Therefore, it is necessary to fill the gaps in these areas. The establishment of a quantitative assessment system for aerobics special movement techniques can scientifically monitor and evaluate the development level of each aerobic athlete's competitive athletic ability. Thus, there is a unified standard for the assessment of an athlete's technical level. Given the lack of this study, this is the research direction of this study and the basis for the selection of the topic. The physical quality of aerobic athletes is an important basis for their special athletic ability, and the prediction model of athletes' special performance can be accurately diagnosed and evaluated using physical form quality index as the independent variable and special performance as the dependent variable, to clarify the focus and target of training content and improve the scientific degree of aerobic training. The initial selection is often made by young children who have not received professional training in aerobics and obviously cannot be selected by examining their aerobic skills. With an assessment model, it is possible to predict their future development potential by testing several physical fitness indicators.

2. Current Status of Research

Memory is ubiquitous in people's lives as a process that enables the storage of experience; for example, the acquisition of life experience and how to learn to use household appliances are all things that memory supports you to achieve [6]. In sports, memory is associated with the acquisition of motor skills. Thus, memory plays an important role in human survival and development. Situational memory is an individual's memory for the experience of an event [7]. This study found that situational memory decreases with age. Situational memory includes memory for events, as well as memory for logical time. Procedural memory is purposeful, practicing motor-operational skills by achieving some purposes, such as skill memory [8]. The quantitative measurement of indicators is ensured to facilitate the quantitative research of specific physical fitness evaluation and training. In the continuous human motion, the energy change during human motion is taken as the idea, and the continuous motion segmentation model of the human body composed of the kinetic energy between joint frames and the potential energy difference between joint frames is established. Memory is initially consciously executed, and after expertise, motor skills become unconscious. At the automatic stage, it is similar to implicit memory, but cannot be totally segregated, with the exception that this component is much reduced. Memory for movement and what can be described as situational memory related to experiential events, and procedural memory related to skill acquisition, are not identical. Action memory can be enhanced by conscious engagement or some descriptive verbal text, or it can be improved by operant learning; it does not exist singularly but is a complex memory process combining multiple attributes [9]. Nowadays, it is studied as a separate field, and its separate division will also help in future research and applications [10].

Traditional methods usually require the manual design of features and their extraction, followed using various machine-learning algorithms to model the proposed features. Sufficient prior knowledge is also required to support the modeling process to achieve a high action recognition rate [11]. Depending on the type of features extracted, traditional-based action recognition methods can be further classified as human geometry-based methods, motion information-based methods, and spatiotemporal interest point-based methods [12]. Deep learning-based action recognition is an end-to-end approach that automatically learns relevant features directly from the original RGB video sequences and uses them for action classification and is divided into dual-stream convolutional neural network-based action recognition methods, 3D convolutional neural network-based action recognition methods, and long- and short-term memory network-based action recognition methods depending on the network structure [13]. At present, there is no clear definition of the concept of human action in the industry, and the hierarchy of actions cannot be accurately classified. Which stages a human action can be decomposed into, which gestures should be included in each stage, and how to determine the start and end time of each gesture are urgent problems to be solved in the future [14].

In competitive aerobics, the flexibility of the joints of the whole body has its specific role in each movement, and anyone movement that is not in place will slow down the process of the full set of movements, making it difficult for athletes to play the technical level. Good flexibility quality can increase the amplitude of the action, make the action more stretching, posture shape more beautiful, and more artistic expression is the basic guarantee of high quality to complete the action. At the same time, good flexibility quality can also effectively prevent sports injuries and extend the life of the sport. Therefore, in the training of competitive aerobics flexibility quality has been an important training content.

3. Analysis of Deep Learning Recognition and Evaluation of Aerobic Movements

3.1. Deep Learning Action Recognition Algorithm. Based on the construction of human action recognition features, the design uses classifiers to recognize and classify human actions based on the features [15]. In recent years, due to the development of deep learning technology, it has many advantages in the field of human action recognition that traditional methods do not have, so it has been widely used, and currently, the field of human action recognition mainly uses two kinds of convolutional neural networks and recurrent neural networks. LSTM neural network solves the gradient disappearance problem of recurrent neural networks and can remember more long-term states. Using a classifier for human action recognition classification is essential to classify the serialized data that have been constructed. In human action recognition, each frame in a sequence corresponds to a moment [16]. To complete the recognition of an action depends not only on the data in the present moment, but also has a strong relationship with the data before this moment, and the whole sequence needs to be analyzed to make a judgment. The emergence of recurrent neural networks solves the serialization problem that traditional neural networks cannot handle. In recurrent neural networks, the output depends not only on the current input but also on the output of the previous layer, and the combination of both determines the final output. The frame interval between the two energy values must be greater than 30 frames, so that the acquisition is completed in sequence. In the end, the frames corresponding to the obtained energy values are arranged from small to large, which is the center of the ten actions obtained by the energy method. There is signaling between the nodes of the hidden layer in a recurrent neural network, and the output of the hidden layer is transformed into a part of the next input; i.e., the output contains the current input and the last output. Having such a special structure allows the recurrent neural network to have the ability to handle sequential data well. Figure 1 shows a diagram of the recurrent neural network structure.

The input gates and the output gates are the control gates: the input gates determine the amount of information to be transferred to the memory cell and the output gates determine how much information from the memory cell will be transferred to the current output. The forgetting gate controls the memory unit and is used to decide between remembering and forgetting the memory unit, and the decision is how much data from the previous moment in the memory unit will be transmitted to the present [17]. Compared with the traditional recurrent neural network, LSTM by introducing a gating structure in it, this structure can well solve the gradient disappearance problem of recurrent neural networks during the training process. At the same time, LSTM can store information for a very long time through the memory unit, which is one of the biggest advantages that distinguish it from other networks. However, too long information will make the LSTM suffer from gradient loss, so it can only play its maximum performance in the appropriate range.

The network input is a fusion feature made by combining four features, and after the previous feature extraction and processing, each human action feature becomes 43-dimensional data, and the length of the data varies depending on the number of frames of each action. Before inputting into the network, each group of data used for training or testing is uniformly processed to equal length for ease of processing, and the remaining sequences are zeroed according to the sequence with the longest sequence in each group. In each period, the data input to the network is a 43-dimensional vector. Next, the intermediate values are fed to the output layer through the computation of the LSTM layer, and the output layer used is the softmax function, which judges the activities and outputs the probability of belonging to each action label, and the corresponding probability with the highest value is the final output class of the network.

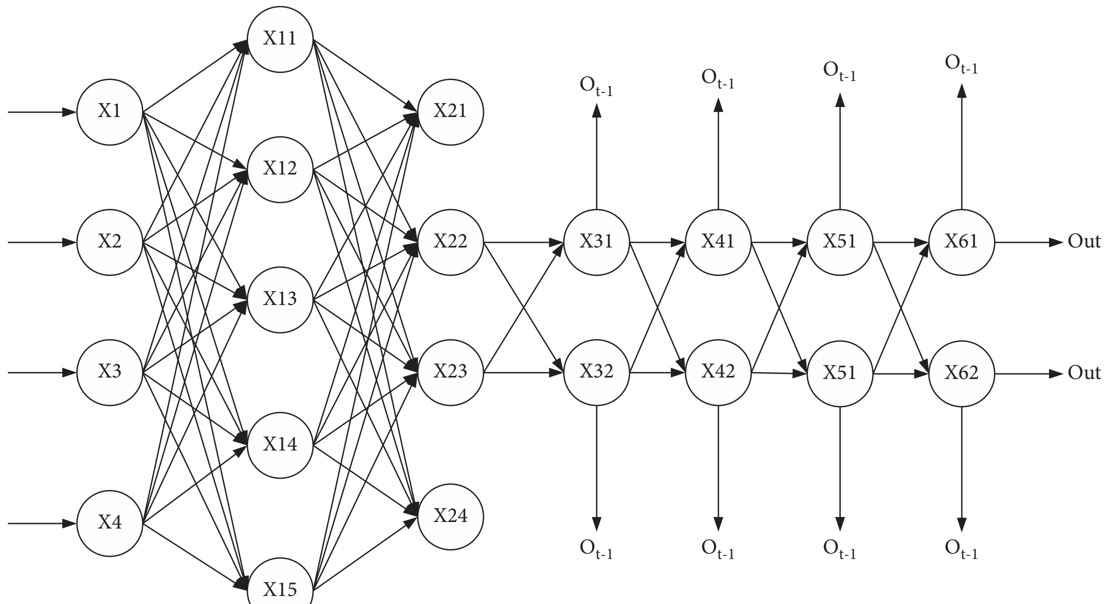

Figure 1: Structure of the recurrent neural network.

$$f_t = \sigma\left(W_f \cdot [h_t, x_t] - b_f\right),$$
$$a_{tn} = \frac{\exp(\mathrm{ent})}{\sum_{t=1}^{T} \exp\left(e_n^t\right)}. \tag{1}$$

In the process of network training, the parameter setting in the model is an important factor that affects the recognition effect of the model. In this chapter, to facilitate the accurate determination of parameters in the network, the grayscale-processed video frames are input into the network for training. Since the grayscale data and the original data are identical in terms of video length, dataset size, and action type except for the single image pixel data, the grayscale images were chosen to initially determine the training parameters for the network structure. Therefore, in this subsection, the number of samples and iterations of the batch data for the network training process will be determined through grayscale graph experiments. The dataset has a significant impact on the effectiveness of the convolutional neural network. Since the duration of human action is not only related to the action, but also related to the active performer, an action lasts from a few frames to tens of video frames, and even for the same action, the number of video frames that the action lasts is inconsistent due to the different action executors. Then, this will also have a great impact on the recognition effect. In the process of recognition, the processing of a different number of frames will also occupy the different sizes of computing resources. To reduce the use of computational resources, before training the network again, the key region of human motion is first detected using the target detection method, and this region is cut out and added to the network as new data for training. Think of it as another action category in addition to all individual action categories. All these individual action categories and transition action categories are used to train the neural network.

$$c_t = f_t c_{t-1} + i_t \tanh\left(W_f \cdot [h_t, x_t] + b_f\right),$$
$$o_t = \sigma\left(W_o \cdot [h_{t+1}, x_{t-1}] - b_f^2\right). \tag{2}$$

In human behavioral movements, not all body movements are equally important, and there are often some that are not so important for the recognition of movements. For example, in the human hand waving action, the main change is concentrated in the upper arm part, and the main change part of the kicking action is in the lower limb part; only the action of this one part is needed to discriminate it, and the action of other parts of the body does not have much influence on the determination of the category. Introducing attention to the human action model, so that it looks for key limb and joint points and gives more attention to them, can be more effective for human action recognition. The main principle of the attention mechanism can be understood as that when humans observe a thing, they do not give equivalent attention to the whole thing, but tend to focus most of their attention on a certain part of the observed thing, which helps humans to use their limited attention to quickly obtain valuable information from a huge number of resources [18]. Because of the presence of attention, it makes human processing of image information very efficient and easy. The attention mechanism is to assign different weights to different parts of things so that they play different importance in the final decision, which is generated through the learning process in the network and is constantly updated. In this study, the attention mechanism is combined with Bi-LSTM neural network for human action recognition, compared with the previous LSTM neural network to make a comparison; adding the attention mechanism to the neural network can calculate the weights of the feature vector output in the network at different time points, find out the important features in the whole human action sequence, and finally improve the accuracy of the whole human recognition network.

$$\begin{aligned} \text{Score}_i &= f\left(Q_t^2, h_i^2\right), \\ \alpha_i &= \text{soft min}\left(\text{Score}_i\right). \end{aligned} \tag{3}$$

First, some neurons in the hidden layer of the neural network are randomly removed, but the neurons in the input layer, as well as the output layer, remain unchanged. Next, the data of human action features are input on top of this network and the data are propagated forward through the neural network, and eventually, the loss values of the network are back propagated after a part of all the training samples are performed in this process and this part of the samples are updated with the parameters on the retained neurons. Finally, this process is kept repeated to recover the previously removed neurons and again some neurons are randomly selected from the hidden layer for deletion, but to record the parameters of the deleted neurons in the training of some of the samples, as shown in Figure 2. According to the athlete's current level, the coach can predict the athlete's possible performance peak according to the prediction model. The coach can calculate the athlete's current physical fitness and the corresponding sports performance and perform the exercise on the athlete according to the athlete's physical function potential and the coach's experience.

Strong attention differs from soft attention in that strong attention considers that every point in an image may be extended to attention, while strong attention is a powerful stochastic prediction process where the system samples randomly from implicit states rather than decoding using all implicit states, with more emphasis on dynamic changes. The bottom line is that strong attention is non-microscopic attention, and the training process is often done through augmented learning. Since the gradients in the network are computed directly and not estimated by a stochastic process, we choose the soft attention mechanism. A temporal attention model is added to the extracted feature model, using a layer of LSTM network with updated weight values.

3.2. Aerobic Movement Evaluation Design. In the process of testing using the metronome after the experiment, the experimental group was able to judge the correct beat of the music faster than before the experiment, and the students' ability to hear and recognize the rhythm of the music was strengthened, and there was a great improvement in their ability to grasp the rhythm of the music, while the control group used the traditional aerobic teaching method, and the teachers paid more attention to the training of the specification of each technical movement of aerobics and the completeness of the set movements [19]. The music is an indispensable part of aerobics, and in the teaching methods and means for the strengthening of rhythm practice, some teachers still do not pay enough attention to the teaching of the early stage of simply teaching the action, so that students are only in the over and over again skilled, and in the late direct use of music practice, the teacher did not teach the process to effectively establish the relationship between

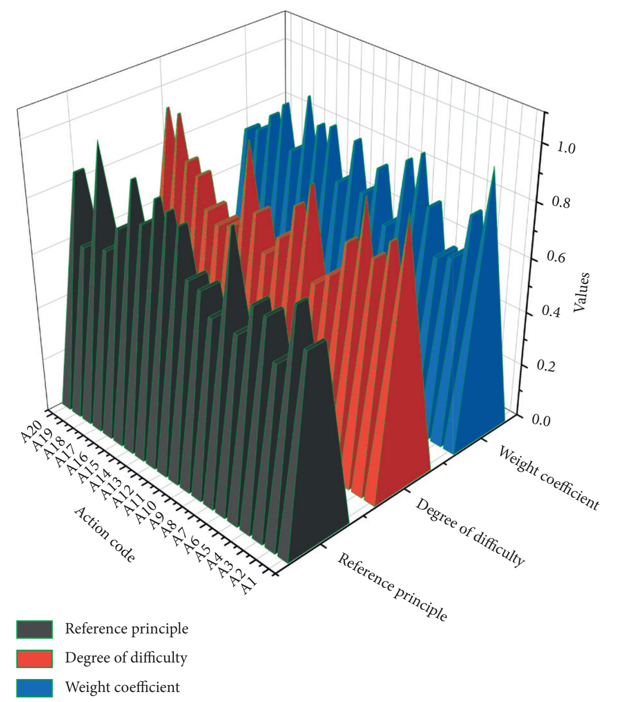

FIGURE 2: Movement indicators for assessing the technical level of specific movements of bodybuilders.

music and sets of movements, so that students lack understanding of music and cannot establish the music. Therefore, the traditional teaching method is not obvious for students to improve their ability to hear and identify music beats, so the experimental group students' music beat reaction time test scores are better than the control group, which has a significant teaching effect.

Physical fitness is the basic athletic ability expressed through the qualities of strength, speed, endurance, coordination, flexibility, agility, etc. It is the core element of competitive ability, and the external form and internal function have an impact on physical fitness. Each project has different requirements for physical fitness. Good physical fitness is the prerequisite for systematic and scientific improvement of performance; it is the necessary guarantee to continuously increase the load and maintain the training efficiency; it is the necessary foundation to improve the competitive state and ensure the level of participation; it is the key to effectively avoid trauma and prolong the training life. The core task of physical training is to improve physical quality and improve external form and strengthen internal functions according to the competitive needs of the project. From the viewpoint of competition time, the set time of aerobics is 80 (±5) seconds, in which athletes need to carry out high-intensity exercise without interval and make endurance adjustments through the action of main content; from the viewpoint of energy supply mode, glycolysis system is the main source of energy of aerobics; and from the viewpoint of action technology, aerobic technology is diverse, and the mastery and play of technology is the key element that dominates the result of participation. In summary, aerobics is a skill-driven sport with short duration, high load intensity, and no intervals, as shown in Table 1.

The external shape consists of length, circumference, density, etc., while internal components are mainly muscle, fat, and body fluid components. The morphological characteristics of athletes vary and differ at different ages. The development of body shape is to some extent the result of quantitative changes in training, which is conducive to the improvement of function and quality, and its changes have an impact on the training effect. For the aerobic program, which is dominated by the judges' subjective judgments, good morphological indicators can enhance artistic expression. To better summarize the morphological characteristics of aerobic athletes, measurements were taken on the athletes participating in the study.

The average height of the participating athletes was 176 cm, with no athletes too tall and no athletes too short. Complexity, variety, and innovation are among the requirements for judging all movement content in the rules of aerobics. Athletes not only need to have the ability to complete complex and varied movements with high quality but also need to have the ability to achieve seamless integration of movement content and music beat, which requires high coordination and agility as well as spatial transformation and perception ability. Good physical fitness can not only lead to the improvement of skills, but also a necessary condition to complete the competition goals and improve the competition performance; excellent strength quality is the guarantee for the realization of the stable improvement of difficult skills. Athletes who are too tall have certain disadvantages in agility and coordination, and they have difficulty in completing large and varied movements, which is not conducive to training and competition; while athletes who are too short have the innate advantage of better agility and coordination, those who are short have a certain disadvantage in artistic aesthetics due to their small range and poor expressiveness in the expression of movement content. Therefore, considering the needs of competition and movement expression, athletes of moderate height are more conducive to aerobic training and competition (Figure 3).

There are many special fitness indicators and complex structures, and different indicators have different effects on the level of special fitness of high-level aerobic athletes in China, and the complexity and operation methods vary in the actual test. Which indicators can reflect the current situation of athletes' special fitness in a comprehensive and representative manner, which indicators are more convenient to obtain data, and which indicators are more conducive to the development of special fitness of aerobic athletes are all indicators of the key elements that need to be considered comprehensively in the selection of indicators. Therefore, before constructing the index system, the principles that need to be followed for index selection should be determined first to guide the selection of the indexes. Firstly, we should consider the representativeness of the indicators, and the indicators with high representativeness can reflect the competition demand more intuitively. This will inevitably be affected by the scale of the competition and the level of the participating players. It is very meaningful to establish a set of evaluation systems for athletes' special sports competence in these sports.

The availability of indicator data is a prerequisite for the scientific conduct of the evaluation.

It is required that the selected or designed indicators can obtain the corresponding data in practical application, avoiding the indicators for which data are not available or accurate data cannot be obtained and ensuring the quantitative measurement of indicators for the quantitative research of special physical performance evaluation and training. In human continuous action with the idea of energy changes during human movement, a human continuous action segmentation model consisting of kinetic energy between joint frames and the potential energy difference between joint frames is established [20]. After visualizing the recognition effect, the recognition results of the single-channel network and the two-speed channel network have the same trend, the difference is that the action recognition changes more smoothly when recognizing the video action after using the two-speed channel, and the overall recognition probability is slightly smaller than the recognition result of the single-channel network, as shown in Figure 4.

To make the evaluation process more objective and accurate, it is necessary to develop a unified evaluation standard that can provide a more intuitive and clear understanding of the differences in the special physical abilities of high-level aerobic athletes. To ensure the objectivity of the evaluation criteria, 16 high-level aerobic athletes were selected to test the index system, and all the athletes selected had the title of the athlete with the rank of general and had won the top 3 places in the authoritative Chinese aerobic events in recent years to ensure the representativeness of the test sample. The data of the athletes were obtained for each index for the follow-up study. This is obviously not enough for our coaches. Modern training programs should be developed in the direction of quantification and accuracy, which urgently needs to establish an evaluation model of the relationship between physical fitness indicators and sports performance.

4. Analysis of Results

4.1. Deep Learning Action Recognition Results. According to the energy model established earlier for the segmentation of continuous action recognition, the energy difference before and after all frames in human continuous action is calculated. Figure 5 is a schematic diagram of the energy of a continuous action obtained after the calculation, the energy between the different two frames has a large difference, and the energy method is based on this for the segmentation of continuous actions. Based on the overall idea that the energy value between two frames when the action occurs is higher than that when the transition action occurs, the segmentation of the continuous action is performed according to the energy value. All the frames of this continuous action are sorted according to the energy value, and the ten frames with the largest energy values are taken to correspond to the ten actions in the continuous action. To avoid that, some individual actions have higher energy values in general, which

Table 1: Body morphometry.

Height	Weight	Leg length	Shoulder width	Chest circumference	Waistline	Hip circumference
Average value	70.3	75.6	41.7	72.5	53.4	44.5
Standard deviation	55.8	82.6	62.7	92	58.2	90.7
Minimum	91.5	60	76.8	58	50.6	50.4
Maximum value	41	42.6	88.9	71.6	94	76.5

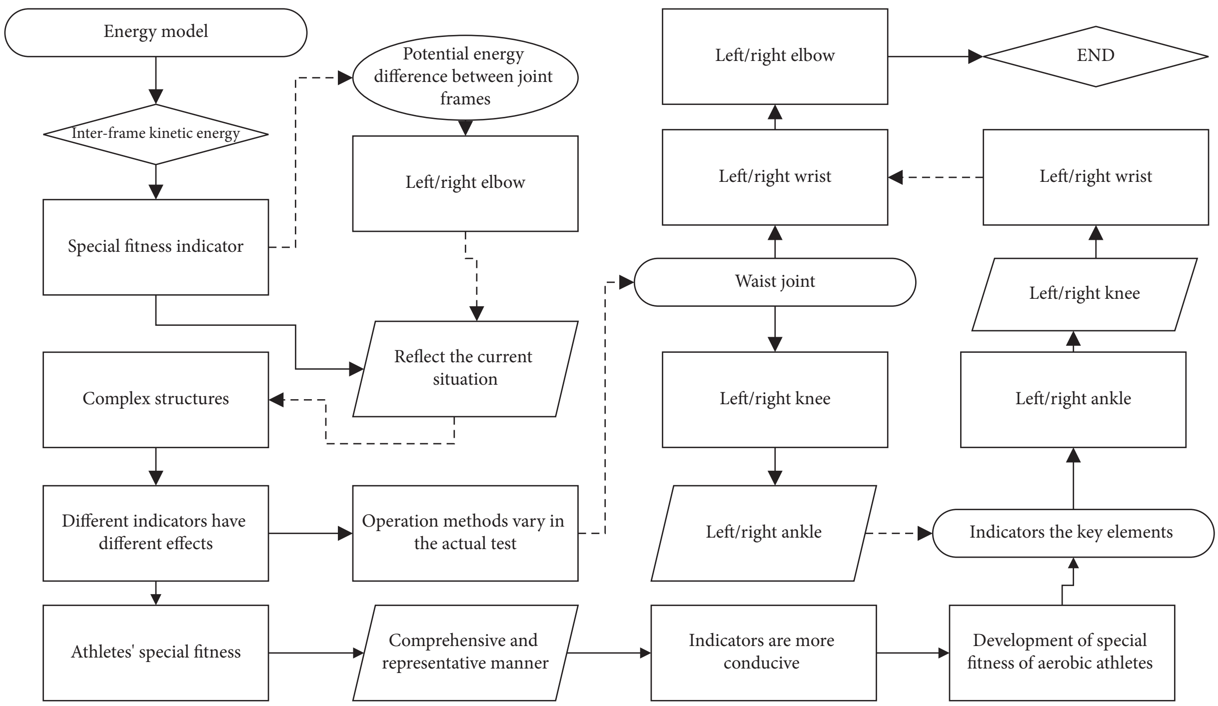

Figure 3: Energy model node composition.

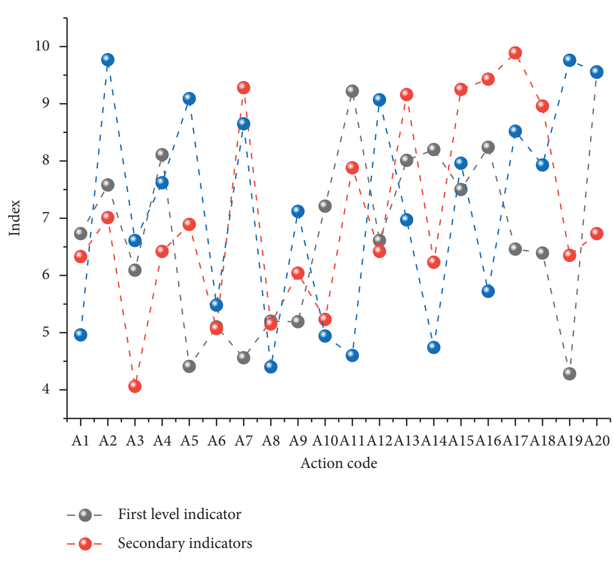

Figure 4: Evaluation indicator system and weighting factors.

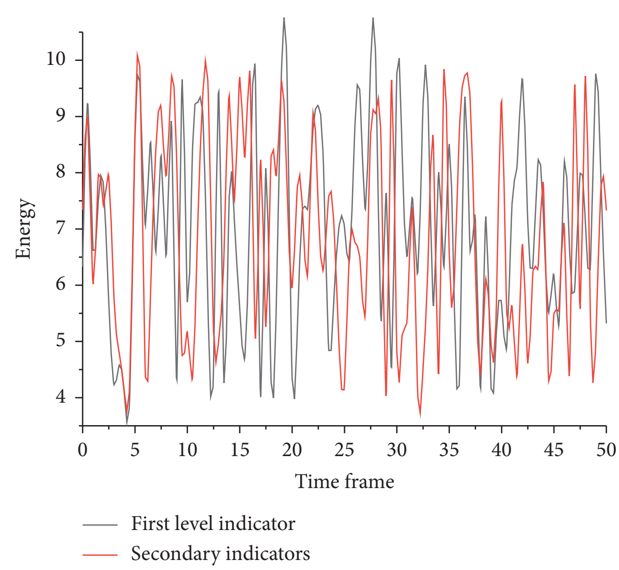

Figure 5: Schematic of continuous action energy.

affects the acquisition, and the interval between two energy value frames must be greater than 30 frames, so that the acquisition is completed in turn. Eventually, the frames corresponding to the obtained energy values are arranged from smallest to largest, which is the center of the ten actions completed by the segmentation obtained by the energy method. The arrows point to the locations of the centers of the actions segmented using the energy method, and the lower line segment is the correct segmentation interval for successive actions. Some of them were effectively segmented, but some of them could not be effectively identified. This is mainly because jitter occurs from time to time during the acquisition of a human continuous action data point, which can cause a dramatic change in the energy value between a certain two frames, causing some degree of interference to the energy method segmentation.

For a human continuous action sequence, the sliding window combined with a neural network classifier has the theme idea of identifying the segmentation while sliding. The neural network classifier is needed in the segmentation process of the human continuous action, and for the training set of the neural network classifier in addition to using the manually segmented individual action sequences in continuous action, there should be transitional action sequences between individual actions and the first and last interspersed action sequences as another action category in addition to all individual action categories. A complex dynamic quality system is formed in the human body, so their influence on the final level is often not linear, and the model established by the multiple regression method is a linear equation. These all individual action categories, as well as the transition action categories, are used to train the neural network. Finally, the segmentation of sequential action sequences of the human body is completed using the trained neural network. In conjunction with a sliding window, the action data are collected at a fixed window size in certain steps, and the neural network classifier completes the recognition segmentation of the actions in the window at that moment and then continues to the next moment window, and when the results of the action categories recognized in the first two moments do not agree, it is determined that the boundary of that action category is reached. When the recognition segmentation of the whole human continuous action is completed, the segmentation result of the continuous action is finally determined after using the screening mechanism to filter and evaluate the segmented actions in the whole human continuous action, as shown in Figure 6.

In the segmentation model of human continuous action recognition based on sliding window combined with the neural network classifier of this study, four of the continuous action sliding window recognition results obtained are shown in Figure 6 below, and a total of ten action classes and one transition action class are recognized. In the recognition experiments of ten actions based on sliding window combined with the neural network classifier of this study for all continuous actions, different step lengths may have an impact on the segmentation recognition of continuous actions, combined with the continuous action database used in this study, the minimum action sequence frame number is below 10 frames, and using a larger step length will cut or jump a certain complete action. Somatosensory technology allows people to get rid of the control of keyboard and mouse and other hardware facilities, and interact with computers more directly and freely, allowing people to integrate into the human-computer interaction environment more realistically. The overall effect of the sliding window on the recognition rate is that the recognition rate decreases as the

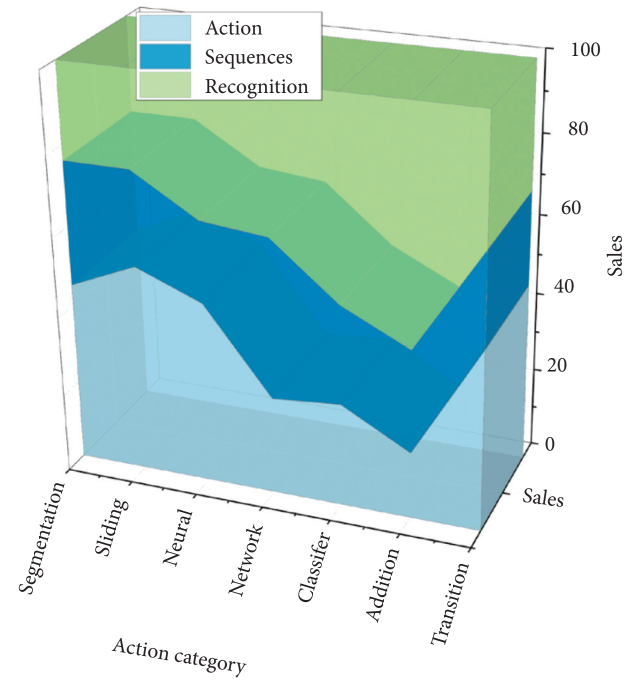

Figure 6: Continuous motion sliding recognition results.

window increases, mainly because the length of each action sequence in a continuous action is mostly concentrated around 30 frames, and using a larger window tends to include transitions outside the boundary, resulting in a lower recognition rate. The maximum recognition rate is obtained at 15 frames mainly because when recognizing an action, the important features tend to be concentrated in a few frames, and the action can be recognized and classified by a few frames.

In this database segmentation problem, two continuous action segmentation methods are given, the energy-based segmentation method and the sliding window-based method combined with the neural network classifier in this study. In the energy-based continuous action segmentation method, an energy model consisting of the kinetic energy between joint frames and the potential energy difference between joint frames is established, and the energy at the time of action is higher than the energy at the time of transition action as the general idea for the segmentation of continuous actions, and the obtained action centers are given time windows of different sizes for experimental simulation. Then, the sliding window combined with the neural network classification built in this study is used to identify the segmentation of human continuous actions, and the initial boundary points obtained are evaluated using a screening mechanism to select the final action boundary in the experimental simulation.

4.2. Results of the Evaluation of Aerobic Movements. The completion of difficult movements and the level of physical training is not a simple superposition of sports qualities, but the result of the comprehensive role of the qualities. Each quality not only has its own functional properties but there is also a complicated interaction between them that not only makes them up but also influences and restricts them. In the human body, a complicated dynamic quality system is formed that affects the overall functional effect. The final score of the difficult action technique is closely related to the structure of physical qualities. The question of what level of each quality should be reached to achieve the ideal score for difficult movements is related to whether the athletes' physical quality potential can be fully utilized and brought into play. Therefore, it has been widely used. Currently, convolutional neural networks and recurrent neural networks are mainly used in the field of human action recognition. Therefore, the development of evaluation criteria for the final score of difficult movement techniques and the level of physical quality development plays a crucial role in the development of training plans to improve the final score of difficult movements. The difference in the difficulty score itself gives a different value to the difficult movements. The higher the difficulty score, the higher the technical and physical requirements of the athlete to complete the movement. If the difficulty factor is too low, it will not be possible to open the gap between the technical levels of the movements of individual athletes. Therefore, we should try to choose the movements with a higher difficulty coefficient as the evaluation index, as shown in Figure 7.

Usually, the development of a professional-level aerobic athlete is long-term and requires the selection of potential recruits starting at a young age. In early selection, we can test the six basic quality indicators of the prospect, which can predict the potential that the prospect has in the sport of aerobics through the prediction model, and combined with the coaches' own accumulated experience in selection, we can make the early selection more justifiable. LSTM can store information for a long time through the memory unit, which is the biggest advantage that distinguishes it from other networks. However, too long information will cause the LSTM to lose the gradient, so it can exert its maximum performance only in an appropriate range. Based on the existing level of the athlete, the peak performance that the athlete may reach can be predicted by the coach based on the prediction model to calculate the existing physical quality of the athlete and the corresponding athletic performance and make a judgment on the athlete based on the potential of the athlete's physical function and the coach's experience to accurately predict what height the athletic performance of the athlete can reach after a certain period of training. The coaches can measure the changes in the athletes' physical quality indicators and sports performance regularly, compare the measured values with the expected values calculated by theory, and check the sports training effects in stages to make timely adjustments to the training plan so that the whole training process is under control. Coaches should determine the content of training according to the two situations of athletes: for athletes with unbalanced physical quality development, to effectively improve the overall level of physical quality, strengthening the weak links in their physical quality should become the focus of training. For athletes with a balanced level of physical quality development, the content of sports training should be arranged according to the principle of priority development of physical quality.

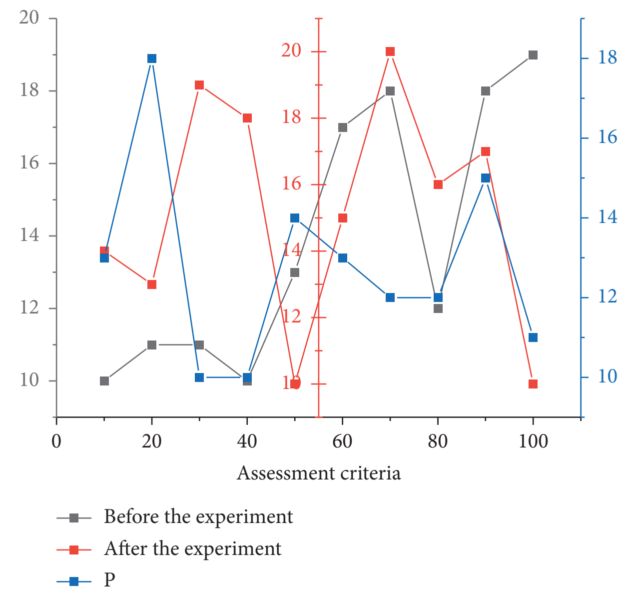

Figure 7: Intragroup comparison of the 8 items of aerobic set performance of the experimental group before and after the experiment.

5. Conclusion

Based on the improved C3D model, a deep convolutional neural network extracts per-frame-based features in the input video. After feature extraction, these features are fed into a temporal attention subnetwork. The temporal attention subnetwork assigns the relevance weight of the features in the recurrent neural network based on the relevance of each feature to the action topic in a positive correlation. This weight is constantly updated during the training iterations of the network during the activity recognition process. The product of superimposed weights and features is used in the temporal attention model to derive the action state information at the current moment, and finally, the decision classification is added to obtain detection results based on the motion state information. This helps humans use limited attention to quickly obtain valuable information from massive resources. Because of the existence of attention, the processing of image information by human beings is very efficient and convenient. In this study, 12 difficult action indicators were selected from 307 movements to reflect the movement skill level of aerobic athletes, and the evaluation table of special movement skill level was developed using the weighting method, and the reliability test results showed that the established evaluation table can accurately reflect the movement skill level of aerobic athletes. The prediction model was established using the method of the neural network, and the reliability and error of this model were analyzed. The error test showed that the evaluation model of body form and quality of aerobic athletes established by the neural network can predict aerobic sports performance and assess the development level of physical quality more accurately.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

Acknowledgments

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Research Article

Online Classroom Teaching Quality Evaluation System Based on Facial Feature Recognition

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With the rapid development of computer big data technology, online education in the form of online courses is increasingly becoming an important means of education. In order to objectively evaluate the teaching quality of online classroom, a teaching quality evaluation system based on facial feature recognition is proposed. The improved (MTCNN) multitask convolutional neural network is used to determine the face region, and then the eye and mouth regions are located according to the facial proportion relationship of the face. The light AlexNet classification based on Ghost module was used to detect the open and close state of eyes and mouth and combined with PERCLOS (percentage of eye closure) index values to achieve fatigue detection. Large range pose estimation from pitch, yaw, and roll angles can be achieved by easily locating facial feature angles. Finally, the fuzzy comprehensive evaluation method is used to evaluate students' learning concentration. The simulation experiments are conducted, and the results show that the proposed system can objectively evaluate the teaching quality of online courses according to students' facial feature recognition.

1. Introduction

Online education, as a brand new education model, has been gradually welcomed by students and parents due to its characteristics of openness and diversity [1]. Online education market has also ushered in a vigorous development, while there are still numerous shortcomings in the actual use process. The biggest deficiency lies in the poor supervision effect of teachers on students in the classroom [2]. In the traditional teaching process, teachers and students are in a limited space. The position of the podium is very good for quick observation of the whole classroom. In the course of class, teachers can control the whole room and effectively supervise students with just a glance. But in online education, the limits of space are broken down. Most of the teacher's attention is paid to the lecture; thus, the rest of the attention cannot effectively control the state of all students, let alone play a supervisory role. For students, online education offers many choices and flexible hours, while the degree of self-discipline is very high. The analysis results of the statistical data of some online education platforms show that there is an obvious phenomenon of learners' poor autonomy in online classroom. This results in a high enrolment rate but a low course pass rate for all kinds of courses [3, 4]. During the COVID-19 pandemic in 2020, some parents reported that the learning effect of their children's online classes at home was very low. This not only causes many students to waste valuable learning time, but also undermines teachers' control over teaching progress and quality.

The COVID-19 pandemic is the first large-scale use of online education to replace traditional education in a short period of time, though it cannot completely replace traditional education at present [5]. However, with the emergence and application of 5G technology, online education has gradually become an important development trend that complements traditional education. Therefore, considering that online education teachers cannot effectively supervise students, the exploration of online classroom teaching quality evaluation system has become an important task of online education development.

Online education has the characteristics of loose structure and open distance teaching environment, in which online learning effect evaluation is an important part. It is very difficult to objectively evaluate the teaching quality of the course via these characteristics [6]. Literature [7] discusses how to improve the learning effect and efficiency of learners through positive emotion and positive emotion in online education. Literature [8] analyses how teachers channel and dissolve students' negative emotions through positive emotions, so as to improve students' learning enthusiasm. Literature [9] builds an emotional interaction model of social learning network, which can identify learners' emotional states in online education. Emotional states include six categories: pleasure, pain, tension, calm, surprise, and disgust. Literature [10] designs a teaching feedback strategy construction method based on emotion learning ontology. In the current research environment, quantitative analysis of student behaviour is an important link of online education. Based on the hybrid teaching mode combining online and offline, paper [11] established online evaluation and offline evaluation systems. The evaluation system focuses on the learning process and teachers can take intervention measures according to the early warning situation.

This paper presents an online classroom teaching quality evaluation system based on facial feature recognition. The innovations and contributions of this paper are listed below.

(1) Face regions are determined by an improved multitask convolutional neural network, and then eye and mouth regions are located according to the facial proportion relationship of the face. The light AlexNet classification based on Ghost module was used to detect the open and close state of eyes and mouth and combined with PERCLOS index values to achieve fatigue detection.

(2) Complete the face pose estimation from pitch, yaw, and roll angles in a wide range through easily located facial feature angles.

(3) Finally, the fuzzy comprehensive evaluation method is used to quantitatively evaluate students' learning concentration.

The simulation results show that the system can effectively evaluate students' concentration in class according to the results of face detection, so as to evaluate the teaching quality of online education.

The chapter structure of this paper is as follows. Section 2 focuses on the proposed algorithm model in this paper. Section 3 is experiment and analysis. Section 4 is the conclusion.

2. The Proposed Model in This Paper

2.1. Fatigue Detection Model. Fatigue detection based on human facial features usually needs to determine the location of the face and eye-mouth and detect the opening and closing state of the eye-mouth. In order to achieve the above functions, this paper uses the improved MTCNN (Multitask Cascaded Convolutional Networks) to complete face detection and key point positioning. Then, the improved AlexNet was used to identify the open and closed state of the eyes and mouth. Finally, the fatigue discrimination was performed according to PERCLOS and PMOT parameters. The fatigue detection process is shown in Figure 1.

2.1.1. Key Point Positioning Based on Improved MTCNN. MTCNN is a face detection and alignment algorithm based on deep learning, which uses image pyramid to detect faces at various scales [12]. Different from multitarget face detection, fatigue detection only needs to precisely locate the human face region. Therefore, the image pyramid part of MTCNN network is improved to achieve face detection and key point location quickly and accurately. Then, after locating the key points, the eye and mouth regions are obtained by using the proportion relation of three courtyards and five eyes of human face. Three courtyards here refer to the length of the face proportion, and the length of the face is divided into three equal points. Five eyes here refer to the proportion of the width of the face, and the width of the face is divided into five equal parts with the length of the eye as the unit.

MTCNN is made up of Proposal Network (P-Net), Refine Network (R-Net), and Output Network (O-Net). The idea of candidate frame plus classifier is used to detect face quickly and efficiently. In order to detect faces of different scales, MTCNN reduces the original image to different sizes to generate image pyramids. The original image is compressed to a certain scale, and the image is traversed with a candidate box of fixed size 12 pixels by 12 pixels. Loop until the reduced image is smaller or wider than the side length of the candidate box. At this point, a picture with a size of 12 pixels $\times$ 12 pixels and channel number of 3 is obtained as the input of P-Net. P-Net uses a convolution kernel with a size of 3×3 to extract image features through convolution operation. Maximum pooling operation was used to remove redundancy. Face classification is used to determine whether the region is a face. Face regions were initially located using bounding box regression and a facial landmark localization. These fields are inserted into R-Net, which will repeat the operations of P-Net. Most of the interference is filtered out; then the reliable face area is retained and input into O-Net. P-Net takes advantage of the feature that the full-convolution output size is 1 pixel $\times$ 1 pixel and the number of channels is 32. R-Net uses a 128-dimensional full connection layer after the last convolutional layer, which preserves more image features. O-Net performs more refined face discrimination, border regression, and key point positioning and finally outputs the coordinates of the face region and 5 feature points. The five characteristic points are left eye midpoint, right eye midpoint, nose tip, left corner of mouth, and right corner of mouth.

The image pyramid constructed by MTCNN contains a large number of images. Sending it into the network to detect all the face areas in the image would take a lot of time. In the

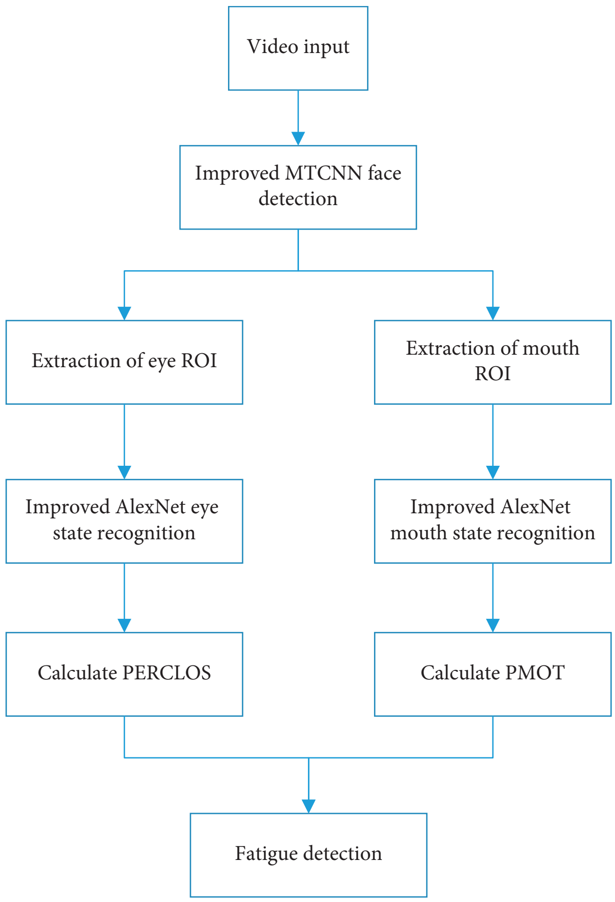

Figure 1: Fatigue detection process.

fatigue detection scene, it is necessary to eliminate the interference of redundant faces and accurately locate human faces. Considering that the human face region occupies a large proportion of pixels in the video frame, this paper amplifies the minimum face size in MTCNN network according to the proportion of human face in the image. The fixed reduction scale is reduced and the first reduction and traversal are skipped. This allows the improved MTCNN network to accurately locate human facial areas. At the same time, it can filter out irrelevant faces in the background and greatly reduce the face detection time.

It is assumed that the coordinate of the left eye obtained by MTCNN is $t_1(\alpha_1, \beta_1)$ and the coordinate of the right eye is $t_2(\alpha_2, \beta_2)$. With extraction of human eye region according to face proportion relationship, its corresponding relationship is shown as

$$\begin{cases} f_1 = \sqrt{(\alpha_1 - \alpha_2)^2 + (\beta_1 - \beta_2)^2}, \\ \omega_1 = 0.5 f_1, \\ \varphi_1 = 0.5 f_1, \end{cases} \quad (1)$$

where f_1 is the distance between the eyes. ω_1 is the width of the eye area. φ_1 is the height of the eye area.

It is assumed that the coordinates of left and right corners of human mouth obtained by MTCNN are $m_1(\alpha_1, \beta_1)$ and $m_2(\alpha_2, \beta_2)$, respectively. The mouth region of human is extracted according to the proportion relation of face, and its corresponding relation is

$$\begin{cases} f_2 = \sqrt{(\alpha_1 - \alpha_2)^2 + (\beta_1 - \beta_2)^2}, \\ \omega_2 = f_2, \\ \varphi_2 = f_2, \end{cases} \quad (2)$$

where f_2 is the distance between the left and right corners of the mouth. ω_2 is the width of the region of interest of the mouth. φ_2 is the height of the mouth area.

Key points were located for the examples in NTHU-DDD dataset [13], and the regions of interest of eyes and mouth were obtained according to the proportion of three courts and five eyes, as shown in Figure 2.

2.1.2. Eye and Mouth State Recognition. The method of eye and mouth state recognition based on manual feature extraction is affected by the shooting angle, shooting distance, and individual differences and has poor robustness. In this paper, the improved AlexNet is used to recognize the open and closed state of the eyes and mouth, which avoids the complex preprocessing operation of the image and has strong robustness.

Ghost module [14] is a lightweight neural network unit. In order to make the fatigue detection model obtain better real-time performance at the edge end, Ghost module is used in this paper to replace all convolution operations in AlexNet. Due to the redundancy of feature images output by deep convolutional neural network, these similar feature images make the feature extraction ability of convolutional neural network stronger. Therefore, Ghost module uses a simple linear operation to obtain more similar feature graphs to improve CNN performance. Ghost module uses a small amount of conventional convolution to get eigen features and then the obtained eigen features through depthwise convolution such a simple linear operation to generate Ghost features. Finally, the intrinsic feature graph and Ghost feature graph are spliced to get the final output. Compared with the direct use of conventional convolution, Ghost module, in the guarantee of accuracy at the same time, greatly reduces the amount of calculation.

AlexNet [15] showed excellent results in image classification based on 8-layer network structure. AlexNet is improved in this paper to classify the open and closed state of eyes and mouth. Since the image of eyes and mouth occupies fewer pixels, the input size of AlexNet is compressed from 224 pixels × 224 pixels and channel number 3 to 24 pixels × 24 pixels and channel number 3. Modify 11 × 11 and 5 × 5 convolution kernels to 3 × 3 convolution kernels. The stride of maximum pooling operation was optimized to avoid too small size of feature graph. AlexNet is only used for eye-mouth state 4 classification, and only the first full connection layer in AlexNet is retained in the model. The output dimension of the full connection layer is changed from 2 048 to 128. Finally, Softmax regression function is used to output the probability that the sample belongs to the open mouth state. The model retains the first layer of traditional convolution to extract image features

Figure 2: ROI positioning of eyes and mouth. (a) Normal state. (b) Yawning state. (c) Slow blink with nodding. (d) Sleepy state.

comprehensively. The other convolution operations are replaced by Ghost module, making the network lightweight. The improved AlexNet architecture is shown in Figure 3.

2.1.3. Fatigue Detection. When a person is in a state of fatigue, there will be a series of physiological reactions, such as long closed eyes, yawning and so on. By calculating PERCLOS and PMOT parameters of continuous video frames, the improved AlexNet model can judge the fatigue state of human with threshold value.

PERCLOS is a physical quantity proposed by Carnegie Mellon Institute to measure fatigue. The correlation analysis of 9 fatigue parameters, including PERCLOS parameters, blinking frequency, and yawning parameters, shows that the correlation between PERCLOS parameters and fatigue state is the highest [16]. PERCLOS parameter represents the percentage of eye closure time in unit time, and the calculation equation is shown as follows:

$$p_{\mathrm{PERCLOS}} = \frac{\sum_x^M h_x}{M} \times 100\%, \tag{3}$$

where M is the total number of video frames per unit time. h_x is the number of closed frames. $\sum_x^M h_x$ is the total number of frames closed per unit time. In the normal state, the value of the PERCLOS parameter is small. When people are in fatigue state, the number of closed eye frames increases, and the value of PERCLOS parameter increases.

The PMOT parameter is similar to the PERCLOS parameter and represents the percentage of open mouth time per unit time. Its calculation equation is as follows:

$$p_{\mathrm{PMOT}} = \frac{\sum_x^M h_x}{M} \times 100\%, \tag{4}$$

where M is the total number of video frames per unit time. h_x is the number of open mouth frames. $\sum_x^M h_x$ is the total number of open mouth frames per unit time. In normal process, the value of human PMOT parameter is small. When a person yawns, the number of open mouth frames increases and the value of PMOT increases.

2.2. Face Pose Estimation Algorithm. Face deflection axis is shown in Figure 4. Among them, the deflection around the X axis is called pitch, the deflection around the Y axis is called yaw, and the deflection around the Z axis is called roll.

In this paper, Adrian Bulat face feature point locator is used to complete face feature point positioning [17], as shown in Figure 5. The positioner is suitable for feature location of rotating face in plane. In addition to the visible feature points, those blocked or invisible face feature points can also be located.

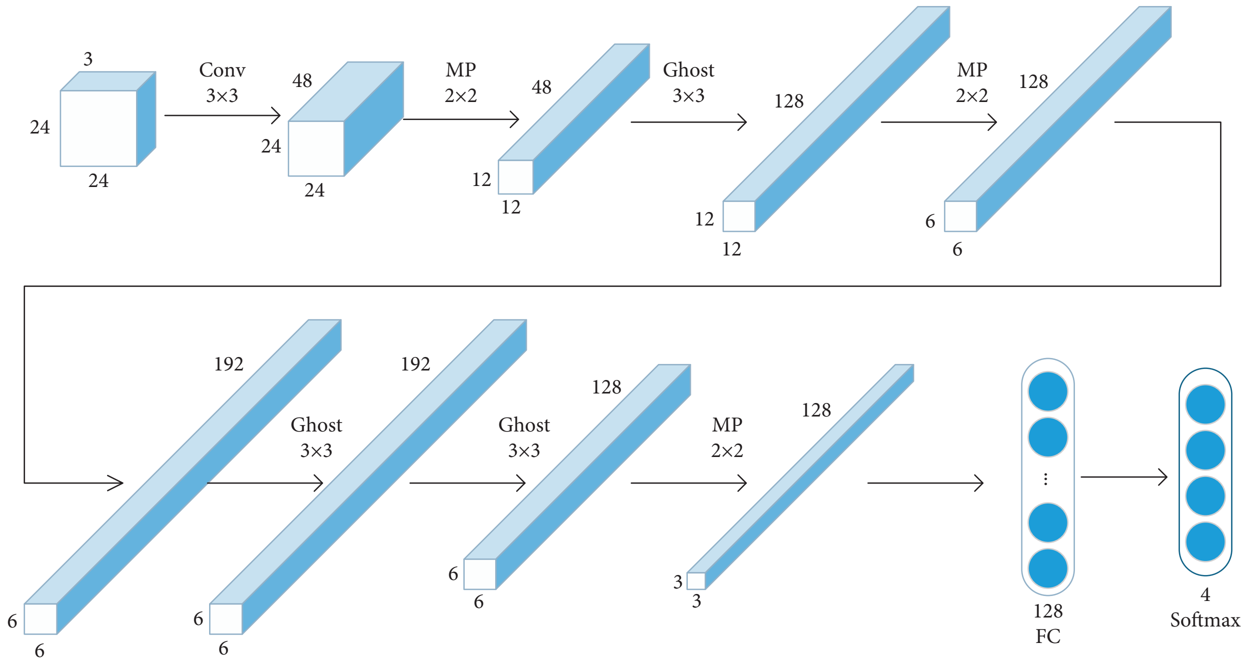

Figure 3: Improved AlexNet architecture.

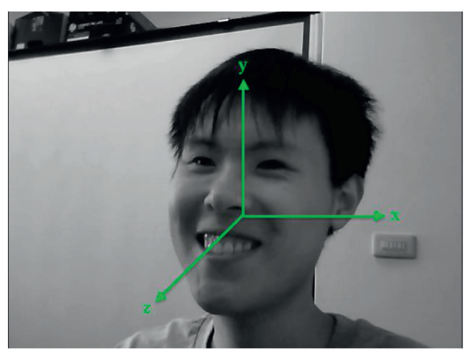

Figure 4: Face posture and its coordinate axes.

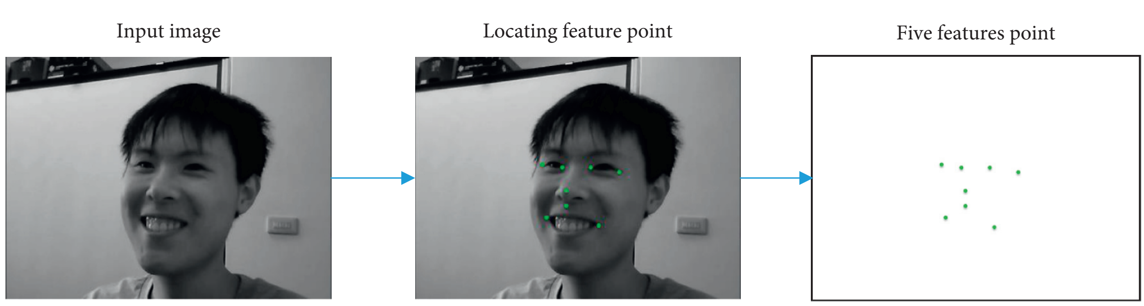

Figure 5: The process of obtaining facial feature points.

Based on facial features, the face pose estimation process adopted in this paper is shown in Figure 6. In order to reduce the estimated parameters in the loss function, the algorithm transforms the process of estimating face rotation around three axes into the process of searching the best rotation angle around X and Y axes within a certain rotation range around Z axis of sparse model. Thus, the roll angle parameter in the loss function is eliminated.

By aligning the subnasal point on the 3D model with the subnasal point on the image, the constraint model can only rotate around the subnasal point to eliminate the translation parameter in the loss function. This makes the loss function retain only the scaling factor, pitch angle, and yaw angle.

Let s be the global dimension parameter of the 3D model; w_α and w_β are the translation parameters in the X and Y directions of the 3D model after the parallel projection to the

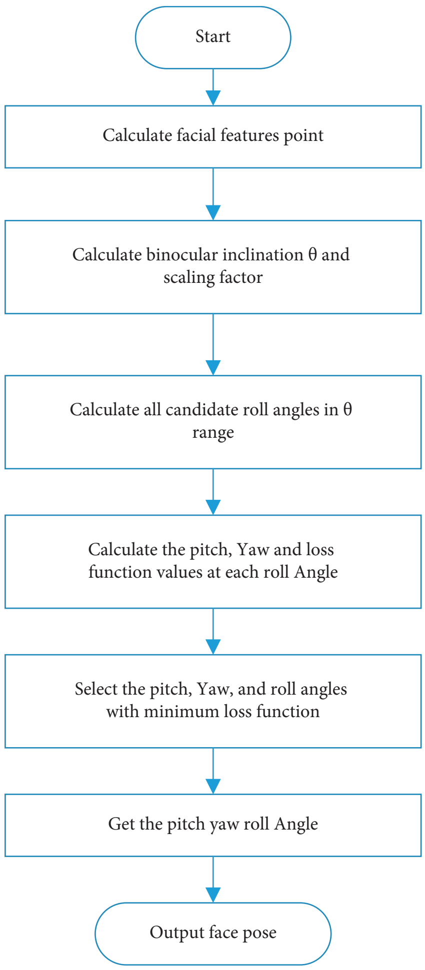

Figure 6: The process of face pose estimation.

XY plane. If face roll angle γ is known, the following method is used to estimate face depth direction deflection angles α and β. The subnasal points of 3D model v were recombined and fixed with the subnasal points of human face on the image. Then, s, α, and β were adjusted to align other feature points on the image with corresponding points on 3D model v after 2D projection (meeting the minimum sum of squares of distance). The equation for the sum of the squares of the minimum distance is as follows:

$$\min h(s,\alpha,\beta) = \min\left(\sum_{x=1}^{t} p_{3\,D} R_{3\,D} S_{3\,D} v_x^{3\,D} + W_{2\,D} - v_x^{2\,D2}\right), \quad (5)$$

$$\begin{cases} W_{2\,D} = v_u^{2\,D} - p_{3\,D} R_{3\,D} S_{3\,D} v_u^{3\,D}, \\ s > 0, \\ \alpha, \beta, s \in R, \end{cases} \quad (6)$$

where t is the number of alignment points, and $v_x^{2\,D}$ is the alignment point on the face image.

$$v_x^{2\,D} = \left(\alpha_x^{2\,d}, \beta_x^{2\,d}, 0\right)^T, \quad (7)$$

$v_x^{3\,D}$ is the corresponding alignment point on model v.

$$v_x^{3\,D} = \left(\alpha_x^{3\,d}, \beta_x^{3\,d}, \gamma_x^{3\,d}\right)^T. \quad (8)$$

$v_u^{2\,D}$ and $v_u^{3\,D}$ are the subnasal points on the face image and v, respectively. $W_{2\,D}$ is the translation vector after the projection of v. $p_{3\,D}$ is v orthographic matrix. $R_{3\,D}$ is v rotation matrix. $S_{3\,D}$ is v global scaling matrix.

Substitute equation (6) into equation (5), and construct the augmented objective function (loss function) using the interior point penalty function method; then it can be obtained as follows:

$$\min H(s,\alpha,\beta) = \min\left(\sum_{x=1}^{t}\left\| \mathrm{P}_{3\,D} R_{3\,D} S_{3\,D}\left(v_x^{3\,D} - v_u^{3\,D}\right) + \left(v_u^{2\,D} - v_x^{2\,D}\right)\right\|^2\right) + \frac{r_z}{s}. \quad (9)$$

$r_z > 0$ is the barrier factor. The modified Newton method [18] is used to calculate the deflection parameters α and β of pitch and yaw of the image face satisfying equation (9) at the specified γ angle, as well as the scaling coefficient s of 3D face model v.

In this paper, the estimations of face in-plane rotation angle and out-plane deflection angle were combined, and the final estimation of face deflection angle around each coordinate axis was obtained by searching for the best deflection angles α and β are within the range of $\theta \pm 90^\circ$ based on the angle θ of the two-eye center line.

2.3. Fuzzy Comprehensive Evaluation. In practical problems, objective decision is often a comprehensive decision of many factors. Some attributes are ambiguous, cannot be quantified, and cannot be judged simply by “good” or “bad.” Fuzzy comprehensive evaluation decision is a comprehensive evaluation method based on fuzzy mathematics [19]. The basic idea is to use fuzzy linear transformation principle and maximum membership principle. Fuzzy attributes are quantified by membership function and evaluated by traditional quantitative evaluation method. In this way, the quantitative and qualitative factors in the problem can be uniformly dealt with, and the differences between fuzzy attributes can be taken into account.

The evaluation objective of this paper is learning concentration. It cannot be quantified in the academic world and belongs to the fuzzy goal. Facial orientation and fatigue degree are also fuzzy in evaluation, so fuzzy comprehensive evaluation is adopted in this paper. The mean value of horizontal facial deflection angle, vertical facial deflection angle, times of eye closure, and times of yawn per unit time are the first level factors. Facial orientation and fatigue were the second factors. Therefore, this paper adopts fuzzy comprehensive evaluation oriented to multilayer factor evaluation, that is, multilevel fuzzy comprehensive evaluation.

2.3.1. Factor Evaluation of the First Layer. The head posture score was divided into turning head score and raising head score, and the minimum value was taken for the comprehensive score. Firstly, the mean of left (right) head turn angle θ_1 and the mean of raised (low) head angle θ_2 were calculated. According to the left and right rotation range of human cervical vertebra joint is $\pm(60^\circ \sim 80^\circ)$. 70° is taken as the maximum left (right) head rotation angle in this paper. The smaller the angle θ_1 is, the higher the score is.

$$z_1 = \begin{cases} 1 - \dfrac{|\theta_1|}{70^\circ}, & 0^\circ \leq |\theta_1| \leq 70^\circ, \\ 0, & |\theta_1| > 70^\circ. \end{cases} \tag{10}$$

The angle of raising (lowering) head of human cervical vertebra joint is $-60^\circ \sim +60^\circ$. When the angle is greater than 0°, it is judged as the head, and when the angle is less than 0°, it is judged as the head. The closer the angle θ_2 is to 0, the closer the head is to the ground, indicating that the learner is looking straight ahead. So the closer the angle θ_2 gets to zero, the higher the score is.

$$z_2 = \begin{cases} 1 - \dfrac{|\theta_2|}{60^\circ}, & 0^\circ \leq |\theta_2| \leq 60^\circ, \\ 0, & |\theta_2| > 60^\circ. \end{cases} \tag{11}$$

The comprehensive score takes the minimum value as

$$\rho_1 = \min(z_1, z_2). \tag{12}$$

In this paper, a comprehensive score of PERCLOS value [20], average length of eye closure, and yawning frequency was used to evaluate fatigue. The comprehensive evaluation of concentration included τ times measurement of eye closure, yawn, and head rotation. The total time of τ times detection is W. PERCLOS value t_1 was calculated according to the number of eye closure T1 and detection τ.

$$t_1 = \frac{w_1}{\tau}. \tag{13}$$

The average closed eye duration (t_2) was calculated from the total time (W) of τ times detection.

$$t_2 = \frac{W}{w_1}. \tag{14}$$

Yawning frequency t_3 was calculated according to the number of yawns w_2.

$$t_3 = \frac{w_2}{\tau}. \tag{15}$$

The weights of the three parameters are determined according to their importance. Take the weights of the three as 1, 0.8, and 0.5, respectively, and the comprehensive fatigue score ρ_2 can be calculated as

$$\rho_2 = t_1 + 0.8t_2 + 0.5t_3. \tag{16}$$

2.3.2. Second Factor Evaluation. The multilevel comprehensive evaluation model of fuzzy comprehensive evaluation model was used to calculate the comprehensive score of concentration. The scores for the first tier of factors have been calculated. Facial orientation score and fatigue score were grouped into evaluation factors $p = [\rho_1, \rho_2]$. Analytic hierarchy process was used to calculate the weight of each factor.

The eigenvector is $\Omega = [0.653, 0.347]^T$. The comprehensive score of concentration is the sum of the scores of the two factors and the weight product, and the equation is as follows:

$$\rho = P \cdot \Omega. \tag{17}$$

3. Experiment

3.1. System Development. The computer development system of this system is Win10. The programming language for development is Python. The development tool uses Pycharm. The programming environment is Python 3.8. The system is set to perform a test every one second. Every five times is a detection period.

3.1.1. Image Preprocessing. This system uses OpenCV's own function to open the computer camera and obtain images. If the fetch fails, it is fetched again. To judge the resolution of the successfully obtained image, if its length (width) is greater than 700, the image is reduced to 1/3 of the original image. Grayscale processing of image can reduce the complexity of subsequent calculation. The face feature points of the image are detected using the preloaded DLIB library. If the detection is successful, 68 feature points and ash images are returned. If the detection fails, obtain the image again and perform the above steps again.

3.1.2. Head Posture Assessment. This module firstly obtains face feature points outputted by image acquisition and preprocessing module. The feature points of canthus of both eyes, corners of the mouth, tip of the nose, and subnasal points were selected. Binocular inclination, scaling factor, and all candidate roll angles were calculated. The pitch, yaw, and loss function values at each roll angle were calculated using the modified Newton iteration method. Select the pitch, yaw, and roll angles corresponding to the minimum loss function. Finally, the evaluation value of face pose is output.

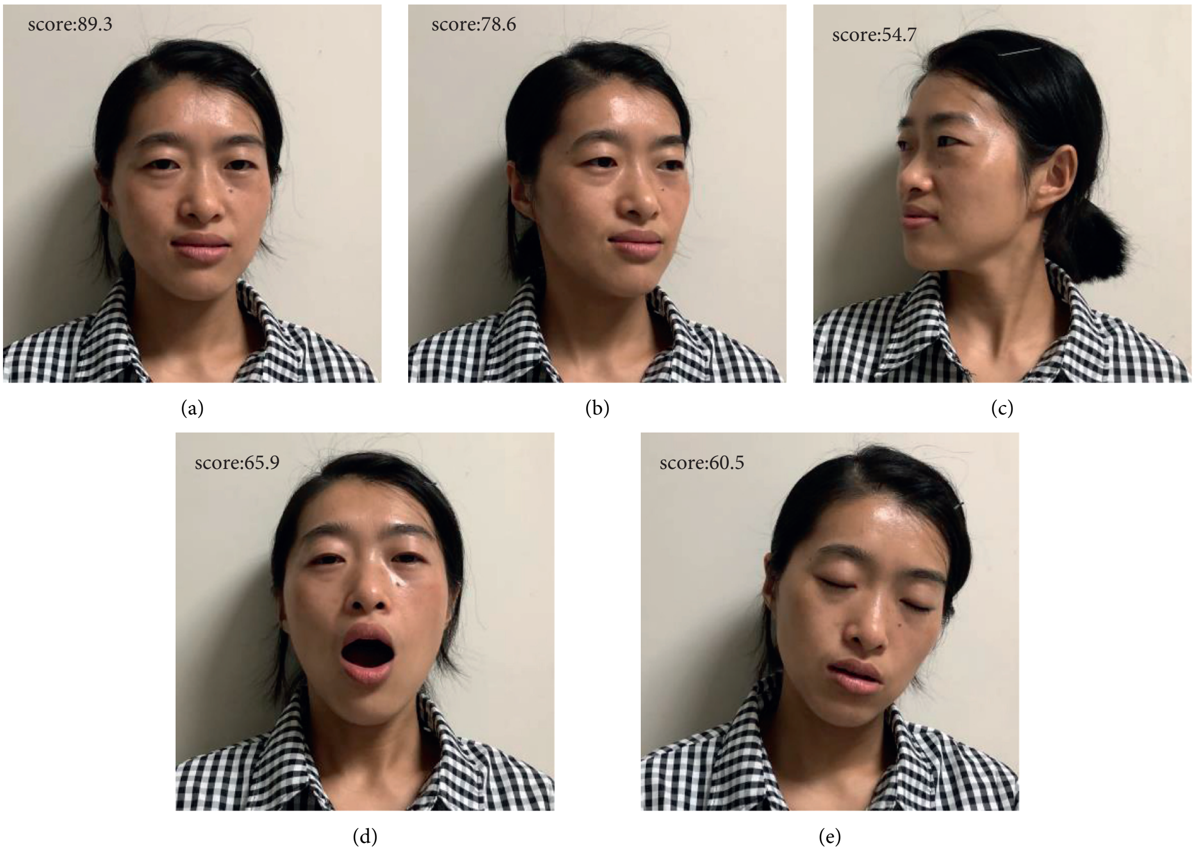

Figure 7: Five learning states of learners. (a) Normal state. (b) Mild head deflection. (c) Severe head. (d) Yawning. (e) Being asleep.

3.1.3. Eye Closure Test and Yawn Test. This module firstly obtains image acquisition and preprocessing module outputs face feature points. Select the feature points of left (right) eye and mouth. The mean value of left (right) eye closure was calculated. Check whether the closure is less than or equal to the threshold. If the condition is met, the number of eye closures is increased by 1. The mouth closure is calculated according to the characteristic points of the mouth to determine whether the closure is greater than or equal to the threshold. If the condition is met, the number of yawns is increased by 1.

3.1.4. Fuzzy Comprehensive Evaluation. The fuzzy comprehensive evaluation module firstly determines whether the detection cycle is over. If not, continue monitoring. At the end, the head posture score and fatigue score were, respectively, calculated according to the detected head raising angle, head left-right turning angle, PERCLOS value, average eye closing duration, and yawn frequency. Then the learning concentration score was calculated based on fuzzy comprehensive score.

3.2. System Experiment. In order to objectively evaluate the teaching quality of online classroom, a teaching quality evaluation system based on facial feature recognition is proposed. The effectiveness of the scheme needs to be tested in practical application. Therefore, a detection scheme is designed in this paper. The subjects were watching a 40-minute teaching video on the computer while the detection system started working. During this process, subjects randomly simulated normal state, nodding state, yawning state, mild head deflection state, and severe head deflection state. It can be seen as Figure 7.

The detection system calculates the mean value of the learning concentration score given by the system to learners in different states. The experimenters were divided into four groups with 20 people in each group. The experimental results are shown in Table 1. For the same learning state simulated by different experimenters, there was no significant difference between the scores given by the system to learners. Compared with the normal state, the scores of learning concentration in other states all decreased to different degrees. In the severe head deflection state and the sleepy state, the decrease of learning concentration score was greater. Combined with the actual situation, severe head deflection and drowsiness will have a very negative impact on learners' concentration. When the head is slightly tilted, it indicates that the learner's attention has shifted to a certain extent, but to a small degree. Therefore, at this time, the system score has decreased relative to the normal state, but the decrease is small. Yawning indicates that the learner's mental state shows fatigue, which will have a great negative impact on their learning concentration. Therefore, the score of the system at this time has a large decrease compared to the normal state.

Table 1: System scores of learner groups in different states.

Learner groups	Normal state	Mild head tilt	Severe head deviation	Yawn state	Sleepy state
1	88.2	81.6	56.2	67.2	59.9
2	87.8	81.7	53.5	66.5	52.7
3	93.1	79.3	55.6	57.9	63.3
4	89.9	79.8	53.9	61.4	63.6

It shows that the system can realize the detection of learners' learning concentration to a certain extent through the simulation experiment of the system designed in this paper. The quality of online course teaching can also be evaluated through this system. At the same time, the teacher can obtain students' online learning concentration in real time at the remote end and master the classroom status. In order to improve the quality of teaching, teachers can adjust the teaching plan to help students learn better.

4. Conclusion

As a new education model, online education is gradually welcomed by students and parents because of its openness and diversity. Aiming to objectively evaluate the teaching quality of online classroom, a teaching quality evaluation system based on facial feature recognition is proposed. Firstly, the improved MTCNN network is used to obtain key points of face. The eye and mouth regions were obtained according to the proportion of three courtyards and five eyes. The improved AlexNet based on Ghost module is used to classify the state of eyes and mouth and make fatigue judgment. Then, the face pose estimation is completed by associating Adrian Bulat face feature point locator. Finally, the effectiveness of the system is verified by simulation experiments. The experimental results show that this system has a good effect on the evaluation of learning concentration and can objectively evaluate the teaching quality of online courses. The analysis and optimization of algorithm efficiency is the content of future work.

Data Availability

The labeled dataset used to support the findings of this study is available from the corresponding author upon request.

Ethical Approval

The authors declare that they obtained image data from public datasets or image data collected by their team, and they obtained authorization to use portrait images in publicly published articles.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

An Improved 2D U-Net Model Integrated Squeeze-and-Excitation Layer for Prostate Cancer Segmentation

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In this paper, we proposed an improved 2D U-Net model integrated squeeze-and-excitation layer for prostate cancer segmentation. The proposed model combined a more complex 2D U-Net model and squeeze-and-excitation technique. The model consisted of an encoder stage and a decoder stage. The encoder stage aims to extract features of the input, which contains CONV blocks, SE layers, and max-pooling layers for improving the feature extraction capability of the model. The decoder aims to map the extracted features to the original image with CONV blocks, SE layers, and upsampling layers. The SE layer is implemented to learn more global and local features. Experiments on the public dataset PROMISE12 have demonstrated that the proposed model could achieve state-of-the-art segmentation performance compared with other traditional methods.

1. Introduction

Prostate cancer has become a high incidence cancer among men. Early medical detection and diagnosis of cancers could substantially improve the cure rate among patients. Currently, radiation therapy which uses medical ionizing radiation to kill cancer cells is a very common procedure to treat prostate cancers [1]. However, the worst disadvantage of the procedure is that the radiation may damage the cells of surrounding tissue when it kills prostate cancer. For the sake of raising the accuracy of radiation therapy and reducing the side effect in surrounding tissue such as bladder and rectum, more delicate prostate cancer diagnosis and more accurate prostate cancer localization methods are required.

At present, there are two main types of artificial and automatic to achieve prostate cancer segmentation on MRI (magnetic resonance imaging) [2]. The former, however, is gradually being displaced by the latter. Manual segment by radiologists is a time resuming work, and there are subjective differences among radiologists' diagnoses. For example, a radiologist may get a segmentation image differently, and different radiologists may obtain to different results on the same image.

Automatic segmentation methods can help radiologists achieve prostate cancer segmentation result faster with higher accuracy. There are two main methods usually utilized: atlas-based methods and deformable model-based methods [3]. As for the atlas-based method, training images accompanied with their corresponding manual labels are mixed together; then, through nonrigid registration (NRR), a reference image named as an Atlas and labeled Atlas is formed [3]. The Atlas is a trained image which represents the prostate and its surrounding tissue while its corresponding labeled Atlas shows the probability of a voxel being a part of the prostate [2, 3]. In model-based methods, the model can use the atlas-based segmentation for its initialization and use the grey-level information of the image to be deformed to match the boundaries of the prostate [4]. Then, a distance metric is utilized, usually the Mahalanobis distance to match the contour of the feature model with the contour extracted from the case images [3]. Both methods can be time-consuming since they require a good initialization to display better effects on prostate cancer segmentation [2].

Currently, the deep learning-based methods have made a remarkable performance in medical image segmentation. There are some research studies based on deep learning methods that have obtained accurate results in the segmentation, which prove that a well-trained deep learning model can improve the accuracy and velocity in medical image segmentation [5–7]. Karimi et al. put forward a two-step segmentation method which contains two convolutional neural networks (CNNs), where the first CNN determines a prostate bounding box and the second CNN provides accurate delineation of the prostate boundary [5]. Guo et al. designed a deformable MR prostate segmentation method by integrating deep feature learning with sparse patch matching [6]. Cheng et al. presented a supervised learning framework which merges the atlas-based active appearance model (AAM) and support vector machines (SVM) to achieve a high segmentation result of the prostate boundary [7]. However, all the methods mentioned above have a common disadvantage in which it is difficult to achieve a pixelwise level segmentation with high accuracy.

Fully convolutional networks (FCN) proposed by Long et al., where the last fully connected layer of regular CNN is replaced with a convolution layer, can obtain the classification information of every pixel; therefore, it solves the problem of pixelwise level segmentation [8]. Roneneberger et al. made a further optimisation based on FCN and presented a symmetric structure called U-Net, which is a regular CNN with an upsampling operation, where deconvolutions are utilized to increase the size of feature maps [9]. At present, FCN or U-Net becomes the most popular backbone network in the medical image segmentation field. There are many new structures derived from the FCN or U-Net model after that time. For example, Zhou et al. modified the skip connection between encoder layers and decoder layers based on U-Net and then designed a new model called U-Net++ [10] and Milletari et al. put forward a variant model named as V-Net which can realize 3D segmentation [11]. However, these methods have a common disadvantage that the similar low-level features are extracted by the model repeatedly which results in unnecessary waste of computational resources.

In order to solve the problems above, in this paper, we proposed a more effective model, which utilizes the U-Net as the backbone of our network, and a squeeze-and-excitation layer is added to every convolution operation to select the emphasize the features which are contributed to the prostate cancer segmentation.

2. Related Works

There are many research studies [5, 6, 10–12] took the deep learning method the same with as to achieve prostate cancer segmentation on MRI because it comes to more remarkable performance in the field compared to the traditional method. The idea of making an optimisation based on U-net has attracted much attention in recent years; many related research studies have made good results. For examples, the U-Net++ was proposed by Zhou et al. which modifies the skip connection between the encoder and the decoder to achieve an optimisation [10], and the 3D U-Net called V-Net was put forward by Milletari et al. based on 2D U-Net [11].

The application of the SE layer took much inspiration from the channel attention utilized in a biattention adversarial network designed by Zhang et al. [12], which proves to have a positive effect on improving model performance.

3. Background

3.1. Structure. Our proposed model refers to the U-Net model and fully convolutional network (FCN), which divide the model into the encoder stage and the decoder stage (autoencoder). The overall structure of our model can be seen in Figure 1. The encoder (also called the contraction path) is used to capture the context in the image, and the decoder (also called the symmetric expanding path) is used to enable precise localization. U-Net and FCN are actually very similar and both of them are published in 2015; however, U-Net is a little bit later than FCN. However, there are still some differences between them. Compared with FCN, U-Net is completely symmetrical whose encoder stage and decoder stage are similar while FCN's decoder stage structure is simpler which only uses one deconvolution operation and no more convolution structures such as U-Net. The second difference is about skip connection, FCN uses summation operation while U-Net uses concatenation operation.

3.2. The Activation Layer. An activation layer is always used after a convolution layer to choose if a particular neuron should be activated or not to be activated in U-Net. There are two most common activation functions used in U-Net. The first is rectified linear unit (ReLU) and the second is leaky rectified linear unit (Leaky ReLU). We are going to introduce these two functions in this section.

The ReLU formula is as follows:

$$f(x) = \begin{cases} 0, & \text{if } x \leq 0, \\ x, & \text{if } x > 0. \end{cases} \tag{1}$$

For the Leaky ReLU,

$$f(x) = \begin{cases} x, & \text{if } x < 0, \\ cx, & \text{if } x \geq 0. \end{cases} \tag{2}$$

Compared to the traditional activation function, such as logistic sigmoid, tanh, and other hyperbolic functions, the rectified linear function has the following advantages:

(1) Imitation of biological principles: brain studies have shown that the message encoding of biological neurons is relatively scattered and sparse [13]. There are about 1–4% of neurons working in the brain at the same time. With linear rectification and regularization, we can know the detailed activities in the machine neural network. The logic function reaches 12 at input 0, which is already half full and stable

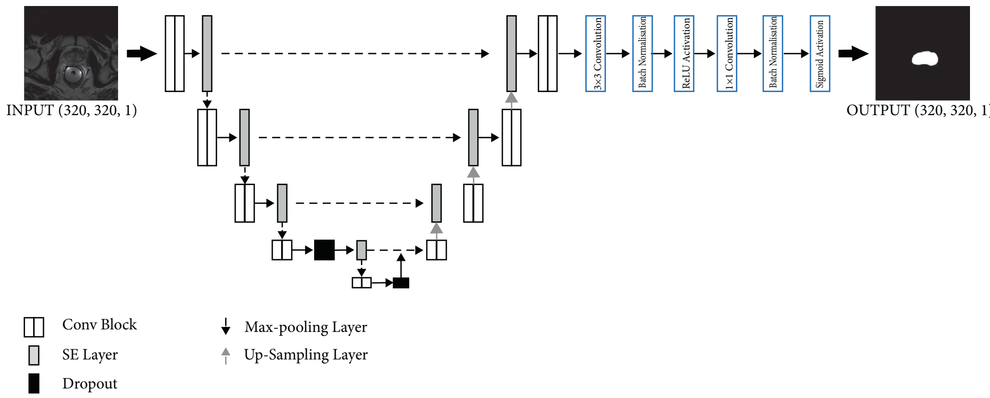

FIGURE 1: Overall structure of the segmentation network. The network includes the encoder and decoder stage connected with skip connection operation. The base components are Conv Block, SE layer, max-pooling layer, and upsampling layer. The first two components will be introduced later.

which is not the same as the expectation of the scientist who think a simulated neural network is the same as the real biology [14].

(2) More efficient gradient descent and backpropagation.

(3) Simplify the calculation: ReLU function can prevent the influence of complicated function, for example, exponential functions, and reduce the total computing cost of the model.

3.3. Dropout Layer. Dropout is a popular way to prevent overfitting in neural network training. In the training process of deep learning network, dropout temporarily discards neural network units from the network with a certain probability, which causes each batch to train a different network model. Use the average to improve the generalization ability of the model. In addition to overfitting, dropout also alleviates the problem of long training time for large-scale neural networks.

3.4. Skip Connections. Skip connection is an operation that skips some of the layer of the network and then takes the output of the layer to feed to the next layers. In U-Net, skip connections were used to fight the vanishing gradient problem and learn pyramid level features [9]. The main idea of skip connections in U-Net is to have the pretrained features and reuse them in the later layer to improve the performance. The features are transferred from the encoder layer to the decoder layer by skip connections which are combined with concatenation instead of summation.

4. Proposed Methods

In this paper, we proposed an improved 2D U-Net model integrated squeeze-and-excitation layer which is used to segment prostate cancer automatically. We are going to introduce our proposed model and the main blocks.

4.1. Model Structure. We did some improvements to the traditional U-Net. Inspired by [8, 9], we added some squeeze-and-excitation (SE) layers, which will be introduced later, based on U-Net. Our model is divided into the encoder stage and the decoder stage; on the encoder stage, the model can effectively extract the input image feature by continuous convolution layer and pooling layer; on the decoder stage, the model will step by step map the extracted features to the original image by the continuous upsampling layer and output predicted mask eventually. Figure 2 is our proposed model, which is more complex than the traditional U-Net. In particular, we added a SE layer before each encoder's pooling layer and after each decoder's upsampling layer.

4.2. CONV BLOCK. We use skip connection operation to concatenate two continuous convolution layer and activation layer and consist of a block and put them into a block which we named as CONV BLOCK. Figure 3 is its inner structure.

4.3. SE Layer. Inspired by [10], calculating the importance weights of each channel and then marking the more useful features, referring to Se-Net's [15] practice, we implemented a method which can extract important features from channels and named it the SE layer; Figure 4 shows its detailed structure.

First of all, we assume feature $F \in R^{H\times W\times C}$, H, W, and C represent the height, width, and channel and number of features is F, respectively, and the function of F is

$$F = [F_1, F_2, \ldots, F_i, \ldots, F_C]. \tag{3}$$

F_i is the i_{th} feature of the channel. For feature F, we use a global average pooling layer (GAP) to generate a vector and named it z_i whose function is

$$z_i = \frac{1}{H \times W} \sum_{x}^{H} \sum_{y}^{W} F_i(x, y). \tag{4}$$

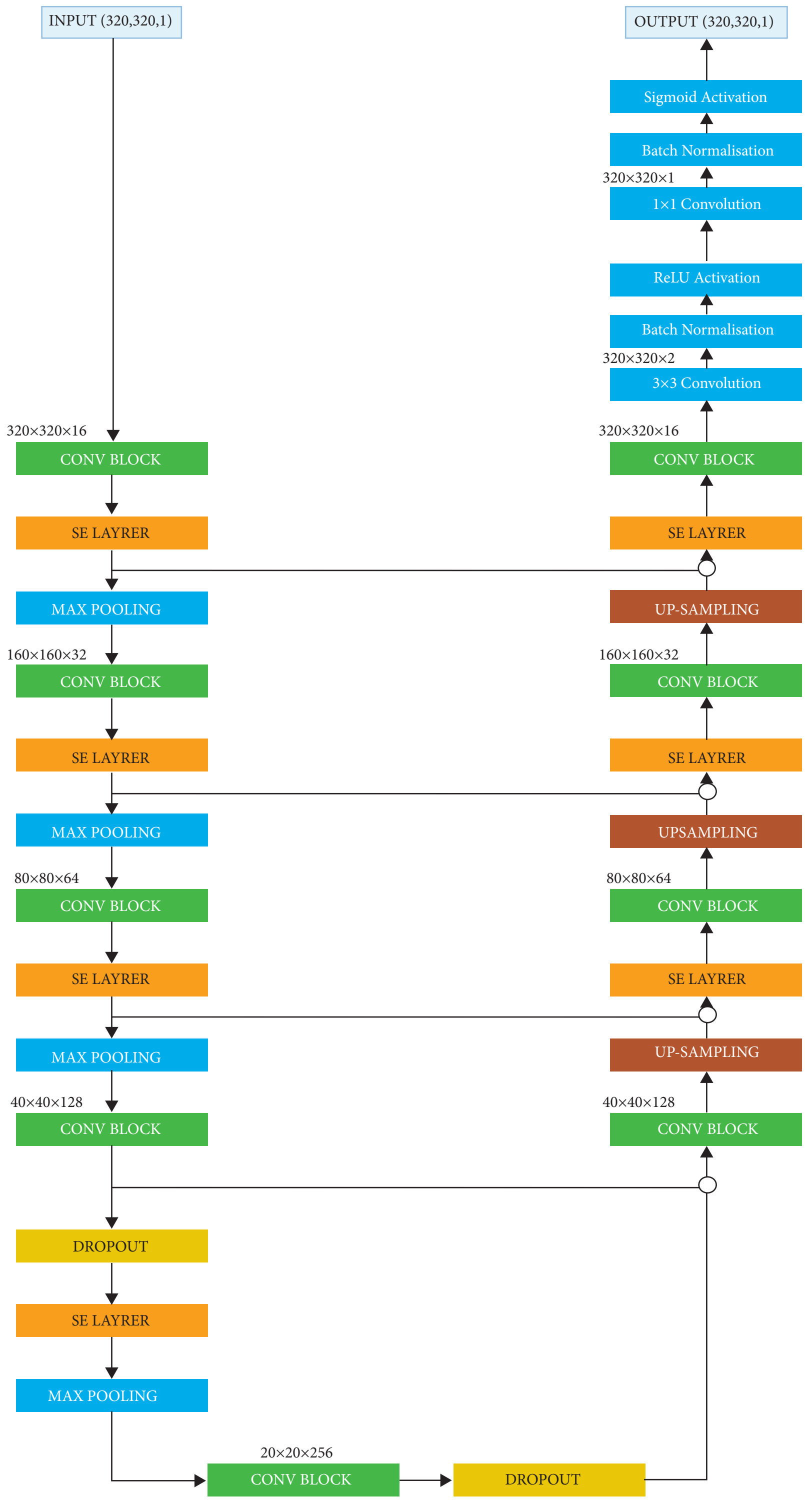

FIGURE 2: Our proposed model structure. The input size is 320×320. And the encoder consists of a series of CONV BLOCK, SE layer, max-pooling layer, and two dropout layers. The decoder consists of a series of CONV BLOCK, upsampling layer, and SE layer. In order to get a 320×320 output, the tail of the decoder consists of two convolution layers, two batch normalisation layers, a ReLU function, and a sigmoid.

z_i is the i_{th} global averaged channel. After that, we use a ReLU activation layer and a sigmoid activation layer to achieve information aggregation as

$$z' = \sigma(W_2\delta(W_1 z)), \tag{5}$$

where σ refers to the ReLU function, $W_1 \in R^{C\times C/r}$ and $W_2 \in R^{C/r\times C}$ refer to the two fully connected layers, and r is a ratio parameter to reduce the dimensional complexity which is set to 4. The importance of each feature channel can be learned and named as z'.

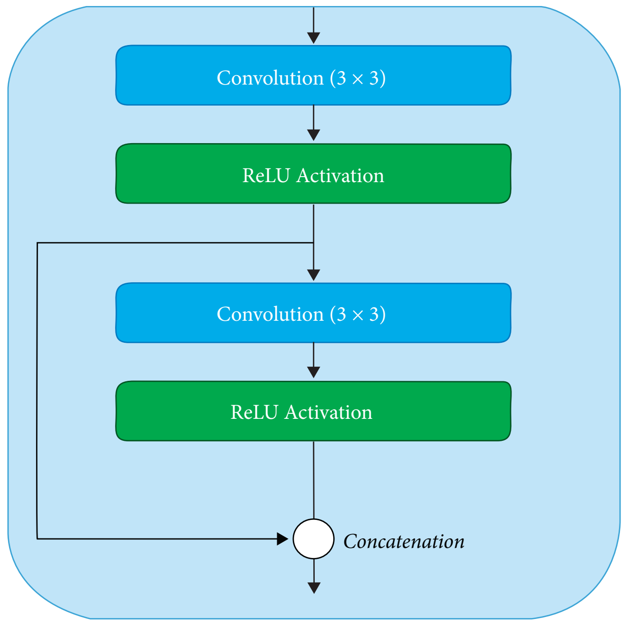

Figure 3: The inner structure of the CONV BLOCK. It consists of two continuous convolution layer and activation layer using concatenate operation.

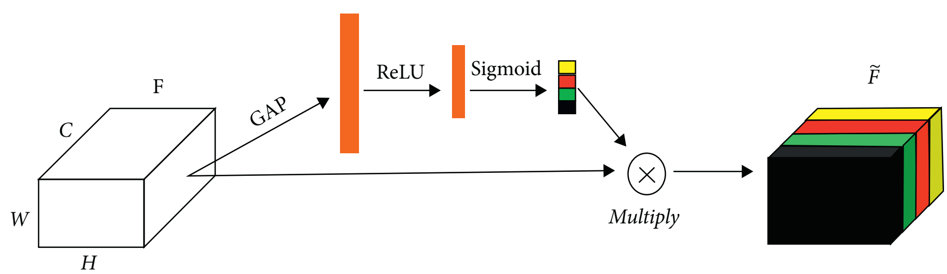

Figure 4: The structure of the SE (squeeze-and-excitation) layer, including a GlobalAveragePooling layer, a ReLU activation, and a Sigmoid activation. F will select important features by a multiply operation as $\tilde{F}$.

We can extract important features by multiplying F with z', and it can be described as

$$\begin{aligned}\tilde{F} &= F * z' \\ &= [F_1 * z_1', F_2 * z_2', \ldots, F_i * z_i', \ldots, F_C * z_C'].\end{aligned} \tag{6}$$

The SE layer is a good way to enhance the ability to learn globally of the model, which is proved to be correct and valid in [15], by strengthening more important features. We use it in both the encoder stage and decoder stage; the detailed location is described in Section 3.1.

4.4. Evaluation Function. We choose Dice similarity coefficient (DSC) as our evaluation function according to [16]. Denote P the predicted mask and GT the ground truth:

$$\mathrm{DSC} = \frac{2|P \cap \mathrm{GT}|}{|P| + |\mathrm{GT}|}. \tag{7}$$

In addition to this, we also choose accuracy (AC), Jaccard index (JA), and sensitivity (SE). TP, FP, TN, and FN represent true positive, false positive, true negative, and false negative, respectively. Their functions can be described as

$$\begin{aligned}\mathrm{AC} &= \frac{\mathrm{TP} + \mathrm{TN}}{\mathrm{TP} + \mathrm{FP} + \mathrm{TN} + \mathrm{FN}}, \\ \mathrm{JA} &= \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP} + \mathrm{FN}}, \\ \mathrm{SE} &= \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}.\end{aligned} \tag{8}$$

5. Results

5.1. Dataset. The performance of the model is evaluated on a public dataset, PROMISE12 dataset, which includes 50 training sets and 30 continuous T2 weighted MR images in each set. We will resize the original image to 320×320 as the input of the model after loading the origin images.

5.2. Training. The designed model is based Tensorflow-Keras library. Our test set and training set all run on 6 GB

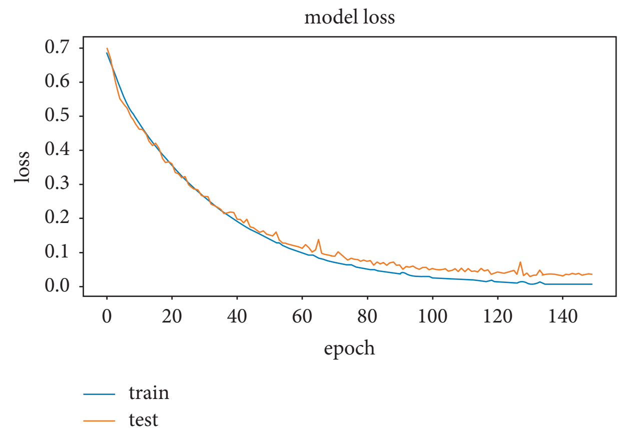

FIGURE 5: The loss curve of the model. The train loss curve dropped gradually to 0.05 and lower until 150 epochs.

NVIDIA GTX 1660TI GPU with Intel (R) Core (TM) i7-9750H CPU @ 2.60 GHz 16RAM. The initial learning rate is 10^{-4}, and the epoch is 150. Before training, we use random flip, rotation, and cropping to augment our training sets to get better training results.

We use an Adam optimizer [17] with a 10^{-4} learning rate as we mention above and a binary cross-entropy loss function [18], given by

$$\text{Loss} = -\left(y_i \log f(x_i, \theta) + (1 - y_i)\log(1 - f(x_i, \theta))\right), \quad (9)$$

where $f(x_i, \theta)$ is the prediction of the network on sample i in a range between 0 and 1 and y_i is the ground truth of sample i in binary 0 or 1.

5.3. Results and Discussion. After the training of 150 epochs using five folds to pick each train set and test set, we can get the model loss and accuracy curves.

As can be seen in Figures 5 and 6, both the loss and accuracy curves perform well, and the effectiveness of the training was preliminarily proved. Two curves remain stable in dozens of epochs, which showed the model is not overfitted. And the gradual decline of the curve demonstrates good convergence of the model.

To show the effectiveness of our model, we implemented three traditional prostate segmentation methods [8, 9, 19]. The work in [8] is fully convolutional networks (FCN), [9] is traditional U-Net, and [19] is a multiatlas method. We will compare our model results to the other three model results mentioned above.

After examining the score in the whole dataset using five-fold cross validation, our model performed well compared to the other three models whose mean DSC is 0.87 and median DSC is 0.89. And the remaining three were also higher than the others.

The detailed five-fold cross-validation results can be seen in Figure 7.

As can be seen in Figure 7, our model performed well on five-fold cross validation. Most of its DSC scores are in the range of 0.70 to 0.95. On the first fold, the median DSC score is above 0.90 and the mean DSC score is a little lower in the range of 0.85 to 0.90. And the second, fourth, and fifth folds are almost like the first fold whose median DSC is around 0.9. And the mean DSC of all five folds is 0.87 which can be seen in Table 1.

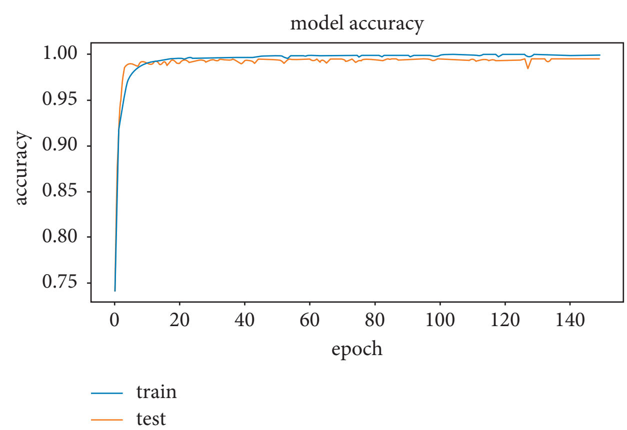

FIGURE 6: The accuracy curve of the model. The train accuracy curve increased gradually to about 0.95 until 150 epochs.

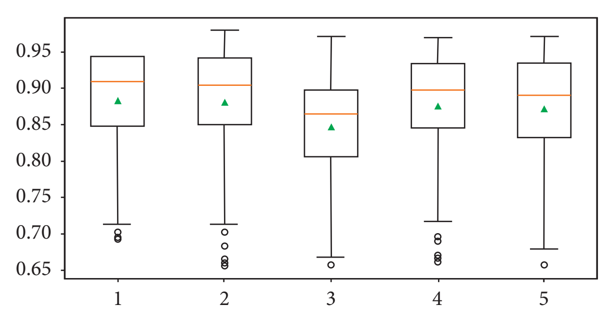

FIGURE 7: Five-fold cross-validation Dice's similarity coefficient (DSC) scores plotting with box-and-whisker. The orange line represents the median DSC score and the green triangle icon represents the mean DSC score on the first fold, the median DSC score is above 0.90, and the mean DSC score is about 0.88. The other folds performed well like the first fold, whose median DSC score is above 0.90 and the mean DSC is in the range of 0.85 to 0.90, except the third fold whose median DSC score is above 0.85 and mean DSC score is a little lower than 0.85.

Table 1: Performance comparison between our model and the traditional methods.

Method	Mean DSC	Median DSC	Mean AC (%)	Mean JA (%)	Mean SE (%)
FCN	0.79	0.81	84.6	72.5	90.6
U-Net	0.81	0.82	85.8	74.0	92.7
Multiatlas	0.80	0.82	85.0	73.5	90.1
Our model	0.87	0.89	87.3	75.3	93.2

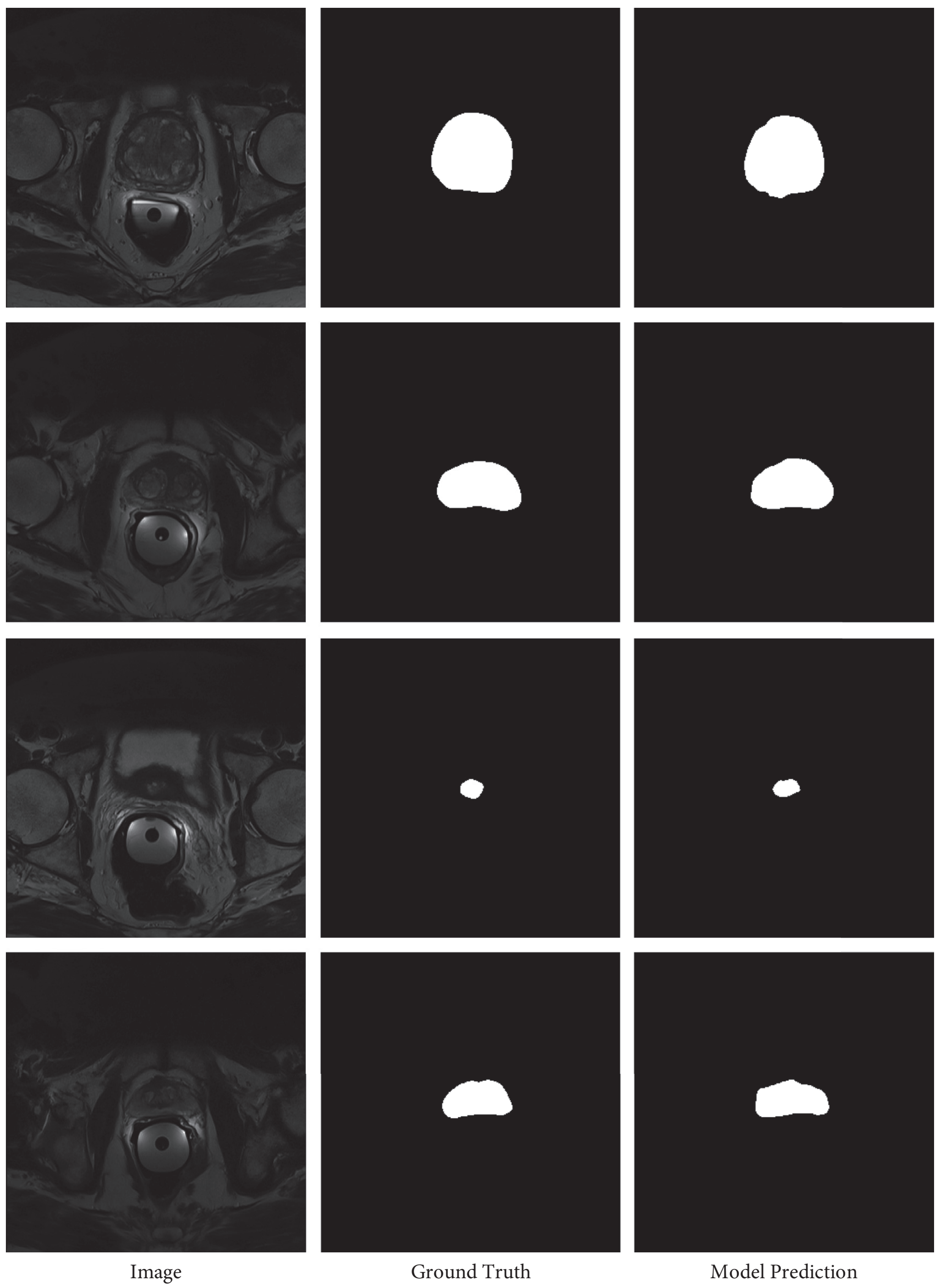

Figure 8: The visualization of some segmentation results in test sets.

6. Conclusion

In this paper, we develop an improved 2D U-Net model integrated Squeeze-and-excitation layer for prostate cancer segmentation. We divided two important components: SE layer and CONV BLOCK. With the SE layer, our model can learn more global and local features. In the CONV BLOCK, we combined feature maps and skip connection with a concatenation operation to bring further improvement in the model performance. In future work, different MRI modalities are going to be tried on our model to segment prostate cancer automatically.

Data Availability

The prostate MRI image dataset can be downloaded from the website (https://promise12.grand-challenge.org/Download/).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

The authors contributed equally to this paper.

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Research Article

Cross-Border Internet of Things E-Commerce Warehouse Control System Based on TRIZ Theory

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Cross-border e-commerce of the Internet of Things is affected by international situations and political factors. Supply chain interruption and returns will cause violent fluctuations in commodity inventory, making the inventory control of cross-border e-commerce very difficult. The TRIZ principle is utilized to solve the problem of the difficulty to evaluate the suppliers comprehensively in e-commerce warehouse management. The Markov algorithm is used to describe the change of inventory level. The cyclic expected time and cost function are constructed by the horizontal crossing method, updating the process and Martingale theory. The effect of the correlation between the demand and supply interruption on the optimal inventory control strategy is studied by simulation. The change of the optimal control strategy under the different interrupt and return types is analyzed, and the validity of the management system is verified.

1. Introduction

The accelerated evolution of cross-border Internet of Things e-commerce has become a new trend of international trade development and a novel engine of national economic growth [1]. To promote the development of cross-border e-commerce, the government encourages the establishment of a comprehensive service system for cross-border e-commerce. At present, the Internet of Things technology is developing rapidly, and the market scale is also in a good situation of expanding. The Internet of Things has turned into an important development strategy for countries around the world. The government has made many policies and plans to promote the in-depth development of the Internet of Things technology so that the industrial system of the Internet of Things constantly improved.

The environment of cross-border Internet of Things e-commerce is increasingly complex, which can be summarized as influenced by three factors. Firstly, the international situations and political factors result in supply disruptions [2]. Secondly, it is affected by the international epidemic, bad weather, and traffic jams [3]. Moreover, the new consumer-related laws and regulations require "seven days without reason to return goods," resulting in a large number of returned goods. These factors interact to create wild swings in inventories. Consequently, the companies increase the costs while reducing the quality of service. Therefore, how to effectively control the inventory under this environment has become a research hotspot in recent years.

Literature [4] studies the joint order decision of retailer optimal pricing when the order demand is out of stock due to price changes. Literature [5] studies the optimal pricing and ordering of the supply chain and its members when the market demand of the products depends on the price and consumers' time preference. Literature [6] constructed a multivariety-combined replenishment inventory model with the demand dependent on the deterioration time based on the characteristics of the nonimmediate deterioration of the products. In the above literature on perishable inventory strategy, the price decision alone was considered, while the replenishment cycle was out of consideration. In some inventory systems, such as the fashion goods inventory, when the goods are out of stock, the length of waiting time for each replenishment will directly affect whether the consumers can accept the delayed arrival of goods. Some scholars have conducted in-depth studies on the combination of the replenishment cycle and pricing. Literature [7] considers the demand dependence of nonimmediate perishable products on the price and product quality and studies the joint decision of the optimal price and replenishment cycle. Literature [8] assumes that price is a time-varying function of the discount rate and initial price, and the demand rate depends on the price and product quality. It studies stock replenishment and pricing decisions for perishable products. The above literature does not consider the impact of the price changes of perishable products during the sales period. Literature [9] analyzes the impact of price discount before product deterioration on unit profit. Others have studied retailers' promotional efforts on perishable goods. Literature [10] takes dynamic pricing, promotion efforts, and delayed payment of the perishable products into consideration and constructs a corresponding joint decision model of ordering and pricing. Literature [11] established a two-stage ordering decision model of dynamic perishable goods sellers to study the ordering decision of the sellers. Literature [12] studies the joint pricing and replenishment of nonimmediate deterioration products on the basis of considering the promotion efforts, price-sensitive random demand rate, and partial delayed order.

People often adopt the inventory defense strategy [13] in addition to the combination of multisource ordering [14] and other means to cope with supply interruptions. Literature [15] evaluated the defensive effects of various strategies. Literature [16], after summarizing the achievements made in the past 20 years, points out that the interruption problem related to the demand and supply state needs to be solved urgently. In this regard, literature [17] studied the use of product substitution strategy to alleviate the panic buying caused by interruptions. To deal with the impact of returned goods on inventory, researchers also put forward many effective measures. Literature [18] studies the inventory control problem in an unrelated environment of return and supply interruption. In addition, for special returns, literature [19] studied the design of the closed-loop supply chain network under the interruption of supply facilities.

Supplier selection is one of the main contents of e-commerce warehouse management. When choosing the suppliers, it is easy to be influenced by the emotional factors of the decision makers. Therefore, there is no quantitative standard for supplier evaluation, and it is difficult to achieve reasonable, objective, and comprehensive evaluation. If e-commerce warehouse management is to continue to develop efficiently and reliably, it is necessary to establish a set of scientific and effective evaluation systems for supplier selection and decision-making. The innovations and contributions of this paper are listed below.

(1) Based on the TRIZ (theory of the solution of inventive problems) theory, this paper makes an in-depth analysis of the e-commerce warehouse management supplier selection to solve the inventory control problem in the environment related to demand and return and supply status.

(2) TRIZ principle is used to solve the problem that it is difficult to evaluate suppliers comprehensively in e-commerce warehouse management.

(3) As the parameters of the Markov modulation model depend on the Markov chain, they are changeable. It allows the pricing models to change with market conditions for better reflecting the objective reality. Thus, Markov is used to describe the change of the inventory level, and the horizontal crossing method and multidimensional martingale theory are used to study the construction of the model. On this basis, the new environment of inventory management enlightenment is put forward by the analysis of the influence of key factors.

The chapter structure of this paper is as follows: the TRIZ theory is described in the next section. The third part mainly introduces the algorithm model proposed in this paper. The fourth part is experiment and analysis. The fifth part is the conclusion.

2. TRIZ Theory

TRIZ is the theory of creative problem solving. It is a set of invention and creation theories put forward by the former Soviet Union's Achishuler and his colleagues in 1946 [20]. For this reason, Achishuler is also known as the "Father of TRIZ." After years of continuous research by enterprises and scholars, the TRIZ theory has formed a systematic theory to solve invention problems, which is shown in Figure 1.

The content system of TRIZ theory mainly includes the following contents.

2.1. Theoretical Basis

(a) Technical systems: It refers to anything that performs or performs a function. A technical system generally has multiple subsystems, and each subsystem is a technical system in its own right. The subsystems of a technical system interact with each other, and changing one subsystem will inevitably affect the whole system.

(b) Conflict is a contradiction: It is another core concept of the TRIZ theory. The TRIZ theory holds that creative problem solving must solve at least one pair of conflicts. In the TRIZ theory, conflict is divided into three categories, namely technical conflict, physical conflict, and management conflict. Technology conflict refers to the deterioration of another feature or parameter when one feature or parameter is improved. Physical conflict refers to two opposite states of a technical system at the same time on a certain characteristic or parameter. Managing conflict is when something needs to be done to achieve certain results or avoid certain phenomena. However, not knowing how to do that means not being able to distinguish between technical conflict and physical conflict.

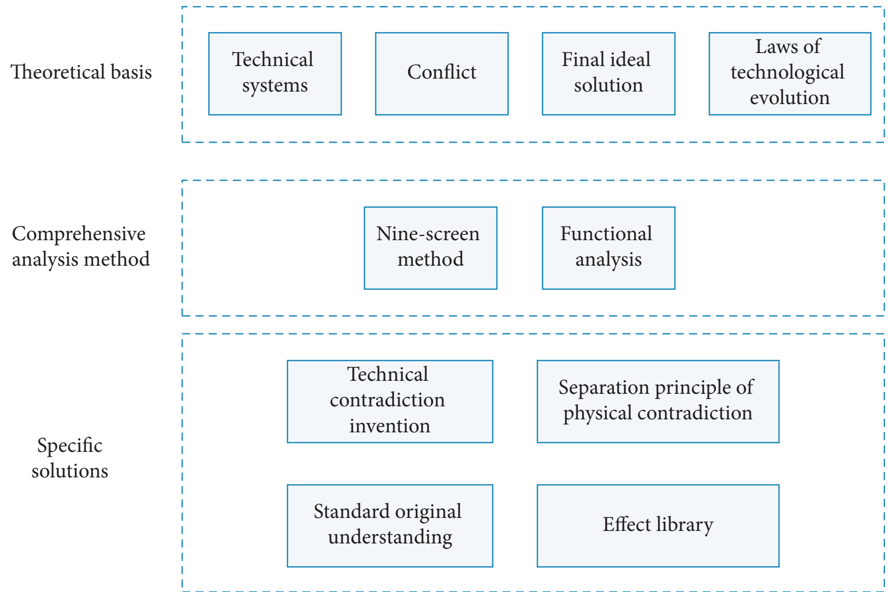

Figure 1: TRIZ system of theory.

(c) Final ideal solution: It refers to a technical system. If it tends to use fewer resources, more features will be provided with fewer side effects. It is a state that tends to be more ideal. The TRIZ theory holds that there is no perfectly ideal technology system. However, the desired end result can be a signpost for innovation. It makes the “ideality” of the technical system increase continuously and gets closer to the final ideal solution state.

(d) The laws of technological evolution: Every technological system is in a state of evolution, in the sense that things are constantly evolving and changing. Achishuler proposed eight rules of evolution. These evolutionary laws can predict the evolution of technological systems, effectively increasing our predictability and moving in their direction.

2.2. Comprehensive Analysis Method

(a) Nine-screen method: It refers to considering not only the current system but also its supersystems and subsystems when analyzing and solving problems. The past and future of the current system are considered. Also, the past and future of the hypersystems and subsystems are taken into account.

(b) Functional analysis: It refers to the technical system as a unit from the perspective of realizing the functions and fully analyzes the system, subsystem, super system, and their internal relations or functions.

2.3. Specific Solutions

(a) Technical contradiction invention principle: It refers to the 40 principles of creation summarized by Achishuler according to the categories of technological contradictions. After the main contradiction is obtained based on the contradiction analysis, it can be solved according to the creation principle corresponding to the contradiction matrix table. There are four main steps to define a technical contradiction. Step one is to know what the problem is. Step two is to know what the existing solutions are. The third step is to identify the shortcomings of the existing solution. The fourth step is to know what is improved and what is worsened, i.e., a pair of technical contradictions are formed.

(b) Separation principle of physical contradiction: It mainly has four separation principles to solve the physical contradiction problems. The four separation principles are space separation principle, time separation principle, conditional separation principle, and whole and part separation principle.

(c) Standard original understanding: It is a construction rule for combining and reorganizing the technical systems. Two functions are contained. One is to help improve an existing system or synthesize a new system. The second is the most effective method to establish the graphical model of the problem, namely the object-field model.

(d) Effect library: In the process of analyzing patents, Achishuler used the principles for many of his existing inventions borrowed from the other fields of scientific knowledge. Therefore, one of the methods proposed in the TRIZ theory to solve the problem is the knowledge base. It means applying the relevant laws of the field, especially in other fields, to solve problems.

3. e-Commerce Warehouse Control System of Internet of Things

3.1. Supplier Selection Model. There are many factors influencing the selection of e-commerce warehouse management suppliers. Combined with the general characteristics of e-commerce warehouse management, this paper chooses factors that are easy to measure to evaluate suppliers according to the extraction principle in the 40 invention principles of the TRI billion theory system. Supplier evaluation is mainly carried out from five aspects: product quality, product price, supplier's technical ability, supplier's management ability, and supplier's service ability. Associated with the invention principles of the TRIZ theory system, the evaluation indexes of the five aspects of the supplier selection are determined, and the supplier selection evaluation model is constructed.

Firstly, according to the universal invention principle of the TRIZ theory, the judgment matrix G of the supplier selection evaluation system is constructed. The product quality H1, product price H2, supplier's technical ability H3, supplier's management ability H4, and supplier's service ability H5 of the four suppliers (C1~C4) are compared in pairs. Their relative importance is judged, and the values of each parameter of the judgment matrix G are listed according to the judgment results. The same method is applied to construct the judgment matrix of H1~H5. Taking the judgment matrix G of the supplier selection evaluation system as an example, the judgment matrix has the following characteristics:

$$\begin{aligned} G_{xx} &= 1, \\ G_{yx} &= \frac{1}{G_{xy}}, \\ G_{xy} &= \frac{G_{xz}}{G_{yz}}, \quad (x, y, z = 1, 2, \ldots\ldots t). \end{aligned} \tag{1}$$

The maximum feature roots and feature vectors of G, H1, H2, H3, H4, and H5 of the supplier selection evaluation system are determined by the combined invention principle of the TRIZ theory. The vector of the judgment matrix G of the supplier selection evaluation system is normalized as follows:

$$G_{xy} = \frac{G_x}{\sum_1^t G_y}, \quad (x, y = 1, 2, \ldots, t). \tag{2}$$

Each column of the supplier selection evaluation system judgment matrix is normalized, and the judgment matrix is obtained.

$$X_x = \sum_1^t G_{xy}, \quad (x = 1, 2, \ldots, t). \tag{3}$$

Divide the vector after adding the judgment matrices of the supplier selection evaluation system by n to obtain the weight vector.

$$M = \frac{X_x}{t}. \tag{4}$$

The calculation will judge the maximum characteristic root $\lambda_{\max}$ of the matrix.

$$\lambda_{\max} = \sum_1^t \frac{(\mathrm{HX})_x}{tX_x}. \tag{5}$$

Combined with the homogeneity invention principle of the TRIZ theory, the consistency test of the judgment matrix of the supplier selection evaluation system is carried out. If the test fails, the model should be rebuilt or the judgment matrix should be reconstructed.

The consistency index CI of the judgment matrix is

$$\mathrm{CI} = \frac{\lambda_{\max} - t}{t - 1}. \tag{6}$$

$\mathrm{CI} = 0$ indicates that the judgment matrix has complete consistency. CI is close to 0, indicating that the judgment matrix has a satisfactory consistency. The larger the CI, the more serious the inconsistency of the judgment matrix.

Calculate the consistency ratio CR of the judgment matrix of the supplier selection evaluation system.

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}. \tag{7}$$

When $\mathrm{CR} < 0.1$, it indicates that the judgment matrix of the product quality has a satisfactory consistency.

When $\mathrm{CR} \geq 0.1$, it indicates that the judgment matrix of the product quality should be rebuilt.

Using the feedback invention principle of the TRIZ theory, the optimal scheme is selected by calculation. Furthermore, synthesize the pros and cons of the last level of the order.

$$W = \sum_g^h X_x \times X_x^x. \tag{8}$$

The final calculation result is the comprehensive score of the evaluation of the supplier in five aspects: product quality, product price, technical ability, management ability, and service ability. The supplier with the highest score is the best supplier choice.

3.2. Warehouse Control System

3.2.1. Problem Description. Assume that a retailer sells a product and accepts returns. Set return without defect after repackaging into the stock as new products to meet the needs of users. The supply state change is described by the state transition of irreducible continuous time Markov chain $Y = \{Y(n), n \geq 0\}$. Here, Y has two states. $Y(n) = 1\,(Y(n) = 2)$ indicates that the time t supplier is in the supply (interrupted) state. Its duration obeys the exponential distribution of $\theta_1\,(\theta_2)$. To obtain the analytical solution, the user demand rate during this period is set as $\mu_1\,(\mu_2)$. The return is a compound Poisson process with the arrival rate $\lambda_1\,(\lambda_2)$, and the batch size follows an exponential distribution with the independent parameter $q_1\,(q_2)$.

Continuous inventory (r, C) strategy is adopted for ordering, i.e., start ordering when the inventory reaches r

level. Assume that the lead time is 0. If $Y = 1$, then the supplier immediately replenishes the inventory to level C. If $Y = 2$, the retailer needs to wait until the supplier outage ends before replenishing the inventory to level C. During the operation of the system, if the inventory level is 0, the demand is lost, resulting in out-of-stock costs. If the return exceeds the limit of the inventory capacity C, the retailer will exceed the part of the discount, and the processing time will be ignored. The return fee (including product cost and packaging replacement fee), handling fee, out-of-stock fee, and inventory fee per unit time are c_r, c_d, c_π and c_a, respectively. The fixed and variable costs of the order are c_f and c_o, respectively. Determine r and C to minimize the retailer's long-run average total expense ratio.

3.2.2. Model Construction. According to the problem description, the inventory level $I(n)$ is a Markov-modulated Levy process starting from C.

$$\begin{aligned} I(n) &= C - Q(n) \\ &= C - \sum_{y=1}^{2} \int_0^n Q_y(\tau) 1_{\{Y(\tau)=y\}} \mathrm{d}\tau, Q_y(\tau) \\ &= \mu_y - \sum_{t=1}^{T_y(\tau)} D_t^y, \end{aligned} \tag{9}$$

$T_y(\tau)$ is a Poisson process, indicating that it returns to the batch at time τ. $D_1^y, D_2^y, \ldots$ is the independent exponential distribution sequence of the q_y parameter and represents the quantity of the returned goods in each batch.

To facilitate the determination of the amount of returned goods, the remaining inventory space process $M(n)$ is analyzed below. Since the returns beyond C are processed, W can be represented as a Markov-modulated Levy process reflected at 0.

$$\begin{aligned} M(n) &= C - I(n) + L(n) \\ &= Q(n) + L(n). \end{aligned} \tag{10}$$

Here, the local time process L_y gives us the amount of returned goods processed up to time T. Obviously, the process in state J is zero.

$$L_y(n) = \int_0^n 1_{\{Y(s)=y\}} \mathrm{d}L(s), \tag{11}$$

where $L(n) = L_1(n) + L_2(n)$. It can be seen from the strong Markov property of Levy process that M is a renewal process. Update the optional interrupt end point at which the supplier completes replenishment.

If M_1 is defined as a subloop running from level 0 to level C, then a loop of M_1 may have multiple subloops embedded in it. If the number of subcycles is T, it can be known from the strong Markov property of Levy process that N follows geometric distribution. Let the running time of the subcycle be τ_1 and the probability that process M_1 reaches the level C corresponding to a state y be u_y.

$$\begin{aligned} &\tau_1 = \inf\{n > 0: M_1(n) = \overline{C} | M_1(0) = 0, Y(0) = 1\}, \\ &u_y = U(Y(\tau_1) = y), \quad y = 1, 2. \end{aligned} \tag{12}$$

The expected number of subcycles is $E[T] = 1/u_2$. The expected time of the M_1 cycle is as follows:

$$\begin{aligned} E[N_1] &= E[\tau_1] E[T] \\ &= \frac{E[\tau_1]}{u_2}. \end{aligned} \tag{13}$$

In addition, let the cycle time of M_2 be N_2, and it can be seen from the description of the problem that N_2 follows an exponential distribution with parameters θ_2. Thus, the expected time of a cycle of process M is as follows:

$$\begin{aligned} [N] &= E[N_1] + E[N_2] \\ &= \frac{E[\tau_1]}{u_2} + \frac{1}{\theta_2}. \end{aligned} \tag{14}$$

The cost function of building the system according to the operation of M is as follows:

(1) Inventory cost function: According to the limit theorem of the renewal process, the stationary distribution function of M_1 and M_2 exists and is set as $M_{1,e}$ and $M_{2,e}$, respectively. The expected inventory cost of a cycle is as follows:

$$E[\mathrm{CB}] = c_b \left\{ \left(C - E[M_{1,e}]\right) \frac{E[\tau_1]}{u_2} + \frac{\left(C - E[M_{2,e}]\right)}{\theta_2} \right\}. \tag{15}$$

(2) Return cost function: since return is a compound Poisson process, the amount of return per unit time is equal to the sum of the product of the amount of return per state and the corresponding state's long-range time. The expected return cost of a cycle is as follows:

$$E[\mathrm{CR}] = c_r \left\{ \frac{\lambda_1}{q_1} \frac{\theta_2}{\theta_1 + \theta_2} + \frac{\lambda_2}{q_2} \frac{\theta_1}{\theta_1 + \theta_2} \right\} E[N]. \tag{16}$$

(3) Deal with the cost function: For phase 1, the desired return processing amount for state y is ℓ_y. For phase 2, where the amount of returned goods is $E[\Gamma]$, the expected return processing the cost for a cycle is as follows:

$$\begin{aligned} E[\mathrm{CD}] &= \& c_d \{E[L(\tau_1)] E[T] + E[\Gamma]\} \\ &= c_d \left\{ \frac{(\ell_1 + \ell_2)}{u_2} + E[\Gamma] \right\}. \end{aligned} \tag{17}$$

(4) Shortage cost function: Shortages occur only in stage 2, and given $E[\Pi]$ as expected shortages, the expected shortage costs for a cycle are as follows:

$$E[\mathrm{CS}] = c_\pi E[\Pi]. \tag{18}$$

(5) Replenishment cost function: The replenishment amount of stage 1 subcycle is $\overline{C}$. Assume that the inventory level before the end of stage 2 is $M_2(N_{2^-})$. Then, the replenishment quantity is $E[M_2(N_{2^-})]$. The expected replenishment cost for a cycle is as follows:

$$E[\mathrm{CO}] = \frac{c_f}{u_2} + c_o\left\{\frac{\overline{C}u_1}{u_2} + E\left[M_2(N_{2^-})\right]\right\}. \tag{19}$$

Based on the renewal reward theorem, the long-term average expense ratio model is constructed as follows:

$$\mathrm{NC}(r, C) = \frac{E[\mathrm{CB}] + E[\mathrm{CR}] + E[\mathrm{CD}] + E[\mathrm{CS}] + E[\mathrm{CO}]}{E[N]}. \tag{20}$$

3.2.3. Determination of Functions in the Model. Since M_1 and M_2 are Markov-modulated Levy processes, it is difficult to obtain the undetermined functions by traditional methods. Kella–Whitt martingale is an effective tool for solving the Levy process problems.

Let Q(n) be a Markov-modulated Levy process. If $K(n) = Q(n) + J(n)$, the equation obtained is as follows:

$$W(\alpha, n) = \int_0^n e^{\alpha K(s)} 1_{Y(s)} \mathrm{d}s F(\alpha) + e^{\alpha K(0)} 1_{Y(0)} - e^{\alpha K(n)} 1_{Y(n)} + \alpha \int_0^n e^{\alpha K(s)} 1_{Y(s)} \mathrm{d}J(s). \tag{21}$$

It is the 0 mean (row) vector martingale, where 1_Y is an N-dimensional row vector whose y$^{\text{th}}$ component is 1 and remainder is 0. $F(\alpha) = V + \mathrm{diag}(\varphi_1(\alpha), \ldots, \varphi_n(\alpha))$ is the matrix exponent of Q(n). V is the state transfer rate matrix of y. $\varphi_1(\alpha)$ is the Levy index of $Q_y(n)$.

For this problem, if $J(n) = L(n)$, then $K(n) = M_1(n)$. The process L(n) only changes when $M_1(n) = 0$, and hence, it is simplified as follows:

$$W(\alpha, n) = \int_0^n e^{\alpha M_1(s)} 1_{Y(s)} \mathrm{d}s F(\alpha) + e^{\alpha M_1(0)} 1_{Y(0)} - e^{\alpha M_1(n)} 1_{Y(n)} + \alpha \int_0^n 1_{Y(s)} \mathrm{d}L(s). \tag{22}$$

Therefore, we can get,

$$\begin{aligned} V &= \begin{bmatrix} -\theta_1 & \theta_1 \\ \theta_2 & -\theta_2 \end{bmatrix}, \quad \varphi_y(\alpha) \\ &= \mathrm{loa} E e^{\alpha Q_y(n)} \\ &= \mu_y \alpha - \frac{\lambda_y \alpha}{\left(q_y + \alpha\right)}. \end{aligned} \tag{23}$$

The matrix exponentials are as follows:

$$F(\alpha) = \begin{bmatrix} -\theta_1 + \varphi_1(\alpha) & \theta_1 \\ \theta_2 & -\theta_2 + \varphi_2(\alpha) \end{bmatrix}. \tag{24}$$

The Kella–Whitt martingale described above is used to determine the function to be solved. Firstly, the optimal sampling theorem for τ_1 is obtained from equation (22).

$$E \int_0^{\tau_1} e^{\alpha M_1(n)} 1_{Y(n)} \mathrm{d}n F(\alpha) + E e^{\alpha M_1(0)} 1_{Y(0)} - E e^{\alpha M_1(\tau_1)} 1_{Y(\tau_1)} + \alpha E \int_0^{\tau_1} 1_{Y(n)} \mathrm{d}L(n) = 0. \tag{25}$$

By $\det(F(\alpha)) = 0$, four roots α_w can be obtained, satisfying the right column vector $F(\alpha_w)h^{[w]} = 0$ right column vector. In equation (25), take $\alpha = \alpha_w$ and multiply with $h^{[w]}$.

$$b_1^{[w]} - e^{\alpha_w \overline{C}}\left(u_1 b_1^{[w]} + u_2 b_2^{[w]}\right) + \alpha_w\left(\ell_1 b_1^{[w]} + \ell_2 b_2^{[w]}\right) = 0, \tag{26}$$

where $w = 1, 2, 3, 4$. To solve this equation, it can be obtained as follows:

$$\left[u_1, u_2, \ell_1, \ell_2\right]^N = H^{-1}\phi. \tag{27}$$

Among them,

$$\begin{aligned} \phi &= \left[b_1^{[1]}, b_1^{[2]}, b_1^{[3]}, b_1^{[4]}\right]^N, \\ H &= \begin{bmatrix} b_1^{[1]} e^{\alpha_1 \overline{C}} & b_1^{[1]} e^{\alpha_1 \overline{C}} & -\alpha_1 b_1^{[1]} & -\alpha_1 b_2^{[1]} \\ b_1^{[2]} e^{\alpha_2 \overline{C}} & b_2^{[2]} e^{\alpha_2 \overline{C}} & -\alpha_2 b_1^{[2]} & -\alpha_2 b_2^{[2]} \\ b_1^{[3]} e^{\alpha_3 \overline{C}} & b_2^{[3]} e^{\alpha_3 \overline{C}} & -\alpha_3 b_1^{[3]} & -\alpha_3 b_2^{[3]} \\ b_1^{[4]} e^{\alpha_4 \overline{C}} & b_2^{[4]} e^{\alpha_4 \overline{C}} & -\alpha_4 b_1^{[4]} & -\alpha_4 b_2^{[4]} \end{bmatrix}. \end{aligned} \tag{28}$$

Then, using the obtained u_y and ℓ_y, simplified for (25), it can be obtained as

$$E\int_0^{\tau_1} e^{\alpha M_1(n)} 1_{Y(n)} \mathrm{d}nF(\alpha) = [\psi_1(\alpha), \psi_2(\alpha)]. \tag{29}$$

Substitute $F(\alpha)$ given in equation (22) into equation (29) and obtain

$$E\int_0^{\tau_1} e^{\alpha M_1(n)} 1_{\{Y(n)=y\}} \mathrm{d}n = \frac{\psi_y(\alpha)\varphi_x(\alpha) - \theta_x(\psi_1(\alpha) + \psi_2(\alpha))}{\varphi_1(\alpha)\varphi_2(\alpha) - \theta_1\varphi_2(\alpha) - \theta_2\varphi_1(\alpha)}. \tag{30}$$

Let $\alpha \longrightarrow 0$ in equation (30), and apply L'Hopital's rule on the right side of the equation.

$$E\int_0^{\tau_1} 1_{\{Y(n)=y\}} \mathrm{d}n = \frac{\theta_x(\overline{C} - \ell_1 - \ell_2) - (-1)^y u_2(\mu_x - \lambda_x/q_x)}{\theta_1(\mu_2 - \lambda_2/q_2) + \theta_2(\mu_1 - \lambda_1/q_1)}. \tag{31}$$

It can be obtained from equation (31).

$$E[\tau_1] = E\int_0^{\tau_1} 1_{\{Y(n)=1\}} \mathrm{d}n + E\int_0^{\tau_1} 1_{\{Y(n)=2\}} \mathrm{d}n = \frac{(\theta_1 + \theta_2)(\overline{C} - \ell_1 - \ell_2) + u_2(\mu_2 - \mu_1 + \lambda_1/q_1 - \lambda_2/q_2)}{\theta_1(\mu_2 - \lambda_2/q_2) + \theta_2(\mu_1 - \lambda_1/q_1)}. \tag{32}$$

In addition, the number of M_1 subcycles in time τ_1 obeys geometric distribution.

$$E\int_0^{N_1} e^{\alpha M_1(n)} \mathrm{d}n = \frac{E\int_0^{\tau_1} e^{\alpha M_1(n)} \mathrm{d}n}{u_2}. \tag{33}$$

Using the ergodic theorem and equation (33), it can be obtained.

$$E\left[e^{\alpha M_{1,e}}\right] = \frac{E\int_0^{N_1} e^{\alpha M_1(n)} \mathrm{d}n}{E[N_1]} = \frac{\sum_{y=1}^{2} E\int_0^{\tau_1} e^{\alpha M_1(n)} 1_{\{Y(n)=y\}} \mathrm{d}n}{E[\tau_1]}. \tag{34}$$

The value can be determined by substituting equations (30) and (32) into (34). On this basis, it can be obtained.

$$E\left[M_{1,e}\right] = \frac{\mathrm{d}}{\mathrm{d}\alpha}\left\{E\left[e^{\alpha M_{1,e}}\right]\right\}\Big|_{\alpha=0}. \tag{35}$$

Equation (35) is easy to be obtained using equation (34), however, the result is long and tedious. Considering space limitation, it is omitted here.

Process M_2 is a Levy process that starts from level C and runs in interval [0, C]. The expectation of steady-state M_2 is zero. It can be obtained as follows:

$$\begin{aligned} E\left[M_{2,e}\right] &= U_0 C + \int_0^{\overline{C}} i f_2(i)\mathrm{d}i + \int_{\overline{C}}^{C} i f_1(i)\mathrm{d}i \\ &= U_0 C + \sum_{y=1}^{2}\left\{\left[\left(C - \frac{1}{\omega_y}\right)e^{\omega_y C} - \left(\overline{C} - \frac{1}{\omega_y}\right)e^{\omega_y \overline{C}}\right]\frac{G_y}{\omega_y} + \left[\left(\overline{C} - \frac{1}{\omega_y}\right)e^{\omega_y \overline{C}} + \frac{1}{\omega_y}\right]\frac{H_y}{\omega_y}\right\}. \end{aligned} \tag{36}$$

4. Experiment

4.1. Simulation Experiment of Supplier Selection. The four alternative suppliers of commodity Z are C1, C2, C3, and C4. The relative weight of each indicator is given by experts according to the importance scale. Construct the judgment matrix of supplier choice A, product quality H1, product price H2, supplier's technical ability H3, supplier's management ability H4, and supplier's service ability H5. Construct the judgment matrix of C1, C2, C3, and C4 relative to the product qualification rate H11, raw material supply condition H12, product production equipment, and product inspection equipment condition H3. The judgment matrix of the supplier choice G and its weight are shown in Table 1. The judgment matrix of product quality H1 and its weight are shown in Table 2.

The supplier selection judgment matrix and its weight are calculated, and the consistency of the constructed judgment matrix is tested. By the analysis of the calculation results, the values of CI and CR are less than 0.1. It shows that the constructed judgment matrix has a satisfactory consistency. According to the calculation, the total score of supplier C1 is 0.2623. The total score of supplier C2 was 0.3044. The total score of supplier C3 was 0.2074. The total score of supplier C4 was 0.2259. Therefore, the four suppliers of commodity A should be selected in priority order: (1) C2, (2) C1, (3) C4, and (4) C3. Therefore, supplier C2 should be selected as the supplier of commodity Z.

Table 1: Supplier selection judgment matrix G and its weight.

G	H1	H2	H3	H4	H5	M1
H1	1	2	3	3	4	0.4033
H2	1/2	1	2	2	3	0.2458
H3	1/3	1/2	1	1	2	0.1384
H4	1/3	1/2	1	1	2	0.1354
H5	1/4	1/3	1/2	1/2	1	0.0771

Table 2: Product quality judgment matrix H and its weight.

H	H11	H12	H13	H14	M1
H11	1	2	3	1	0.3523
H12	1/2	1	2	1/2	0.1898
H13	1/3	1/2	1	1/3	0.1078
H14	1	2	3	1	0.3501

4.2. Simulation Experiment of Supplier Selection. Using the function obtained above, the system optimization model is constructed as follows:

$$\min \mathrm{NC}(r, C) = \frac{E[\mathrm{CB}] + E[\mathrm{CR}] + E[\mathrm{CD}] + E[\mathrm{CS}] + E[\mathrm{CO}]}{E[N]}, \tag{37}$$

where $E[\mathrm{CB}] \sim E[\mathrm{CO}]$ can be calculated by equations (15) to (19). Obviously, the above equation is a nonlinear optimization function with constraints, and its optimal solution can be determined by Matlab.

The purpose of the simulation is to analyze the influence of the system parameter variation on the optimal control strategy r^* and C^* and cost NC^* under the new environment. Referring to the commonly used model of demand and price multiplication, the relationship between the demand rate and supply interruption is defined as follows:

$$\mu_2 = \mu_1 e^{\delta\rho/(1+\rho)}, \tag{38}$$

where δ represents the correlation between the demand and supply interruption. ρ is the interruption intensity (i.e., the ratio of mean interruption time to supply time (θ_1/θ_2). Similarly, the return rates and supply disruptions are defined as follows:

$$\gamma_2 = \gamma_1 e^{-\varepsilon\rho/(1+\rho)}, \tag{39}$$

where ε is the correlation between the returned goods and supply interruptions. Obviously, if δ and ε are 0, then $\mu_1 = \mu_2$, $\gamma_2 = \gamma_1$. It means that the demand and returns are independent of supply disruptions.

The influence of the change of the interrupt intensity and type is studied in the case of demand and interrupts. Here, the change of interrupt type is realized by adjusting the value of recovery rate θ_2 for a given interrupt intensity $\rho = 1$. Other parameters take the basic values, and the optimal results of the system are shown in Figures 2 and 3, respectively.

As can be seen from Figure 2, r^*, C^*, and NC^* increase with the increase of δ or ρ. The reason is that the increase of δ and ρ leads to the increase of the demand rate μ_2. To avoid

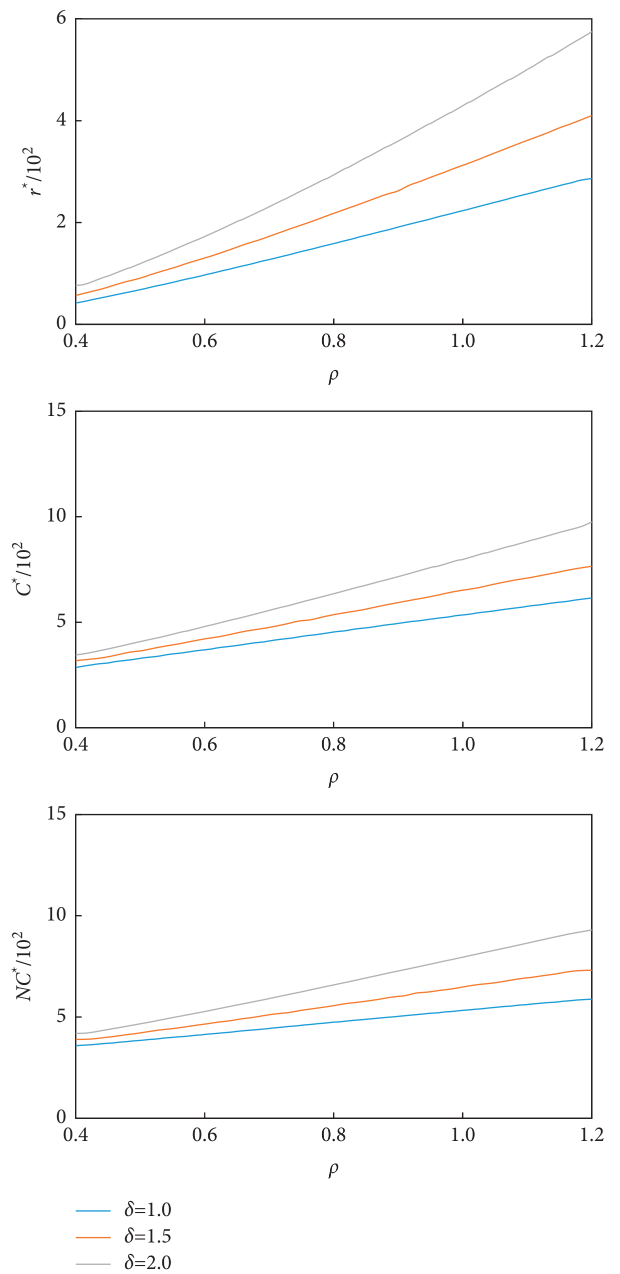

Figure 2: Optimal inventory strategy and cost corresponding to δ and ρ changes.

large shortages and order costs, the retailers raise r^* and C^*, resulting in higher NC^*.

By comparing Figures 2 and 3, it can be seen that the change of interrupt type does not change the influence trend of δ on r^*, C^*, and NC^*. However, with the increase of θ_2, r^*, C^*, and NC^* tend to decrease. The reason for this is that as θ_2 changes from small to large, the interrupt type changes from low frequency with long duration to high frequency with short duration. Suppliers can recover more quickly from disruptions, and retailers do not need to keep high inventories to guard against shortages caused by disruptions. Therefore, both r^* and C^* decrease gradually, and NC^* also decreases.

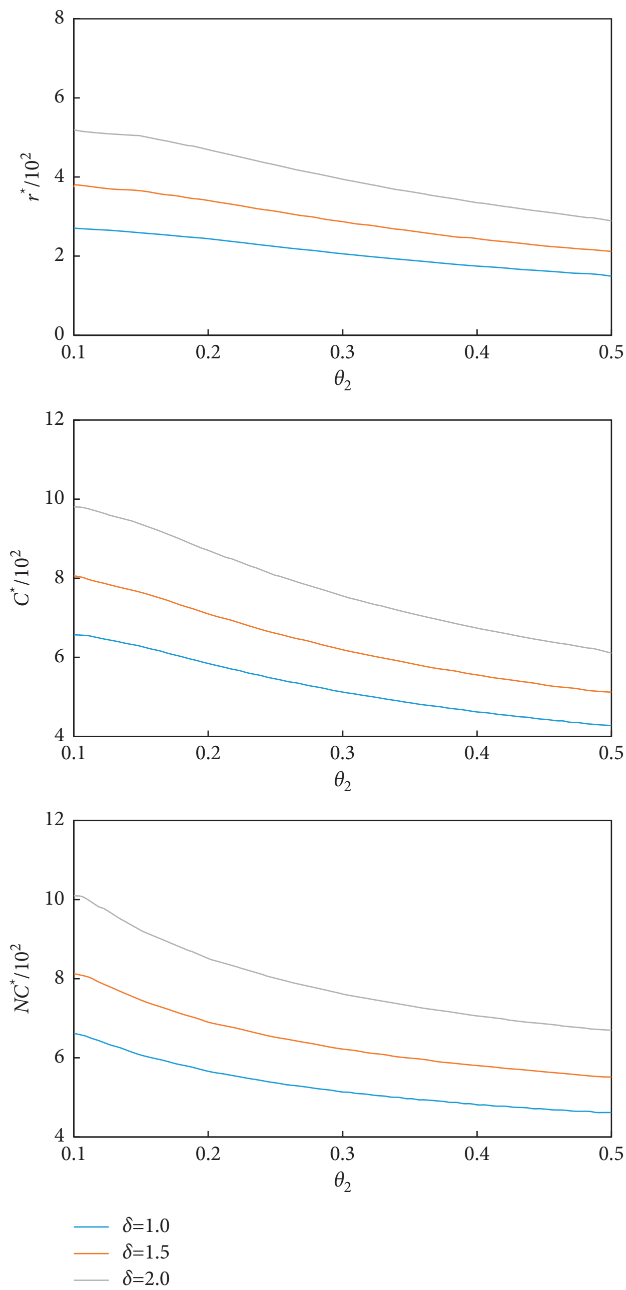

FIGURE 3: Optimal inventory strategy and cost corresponding to δ and θ_2 changes.

5. Conclusion

Cross-border Internet of Things e-commerce is developing rapidly and has become an important development strategy for countries all over the world. However, the environment of cross-border Internet of Things e-commerce is becoming more and more complex, which is influenced by international factors, transportation, policies, and other factors. The supplier selection of e-commerce warehouse management is deeply analyzed based on the TRIZ theory, aiming to improve the rationality of inventory control. With expressing the change of the inventory level as a Markov-modulated Levy process, the model of the system's long-range average total cost ratio is constructed using the horizontal traversal, updating process, and multidimensional martingale theory. The feasibility of the system is verified by a simulation experiment. Future work will add the international trade situation, the climate, and other real-time change factors into the influence factors of the algorithm to make the model more consistent with the objective situation. The efficiency of the algorithm will be analyzed in future work.

Data Availability

The labeled datasets used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

The Influence of Trust on Crowd Logistics Enterprise's Operational Performance: A SEM-PLS Model

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With the development of information communication and satellite positioning, crowd logistics has gradually emerged as a popular urban distribution mode for logistics enterprises. Trust and synergy between the crowd workers and the crowd logistics enterprises have become key issues in urban logistics development. Based on commitment-trust theory and logistics synergy, this paper developed a theoretical model exploring ability trust, goodwill trust, logistics synergy, and crowd logistics operational performance. We used SmartPLS software to analyze the questionnaire survey from 50 senior managers in crowd logistics enterprises. The results show that ability trust has a significant positive impact on logistics synergy and operational performance. Logistics synergy was also found to increase the operational performance of crowd logistics enterprises and plays a mediating role in the impact of ability trust and goodwill trust on operational performance. We recommend that logistics enterprises evaluate their crowd workers' service abilities, promote trust relationships with them, strengthen the construction of crowd logistics mechanisms, and invest in crowd worker training and development.

1. Introduction

With the rise of the sharing economy, many new business forms have developed, including crowd logistics. Crowdsourcing is a collaborative operation that integrates external knowledge and resources with enterprise technology to generate innovation [1]. With the crowdsourcing mode, logistics enterprises can gather scattered and idle external resources [2] and outsource the distribution activities originally performed by their employees to non-fixed social groups through the internet platform [3]. Given logistical difficulties, such as shortages in terminal logistics distribution resources and large fluctuations in market demand, crowd logistics provides an innovative solution to ameliorate delivery efficiency and reduce operating costs [4]. Dada Express, for example, has more than 4 million registered crowd workers on the platform, covering more than 1,400 cities across the country with over 40 million active users [5]. The emergence of crowd logistics has effectively solved the issues of delivery warehouse bursting, difficulties in resource integration, and low-efficiency distribution, resulting in huge economic benefits to enterprises [6]. Meanwhile, advances in information and communication technology, satellite location, and navigation [6] have opened up further opportunities for the crowd logistics development. The platformization and intellectualization of crowdsourcing logistics also match the industry 4.0 era's development needs. As a result, crowdsourcing logistics is becoming increasingly popular in urban distribution.

From the perspective of resources, enterprises regard crowd workers as external resources, achieving resource integration through crowdsourcing [7]. When internal and external synergies are transformed into synergies of enterprises, enterprise performance can be elevated [8]. However, while crowd logistics can promote cost reduction and increase efficiency, problems such as consumer information leakage and mishandled or damaged parcels occasionally happen. Some major reasons for these problems include immature development of the practice, weak stickiness of the public, and non-employment of crowd workers [6]. In particular, trust issues between the enterprise and crowd workers are prominent [6, 9], affecting enterprises' synergy efficiency, service quality, and operational performance.

At present, studies on the impact of trust in the operational performance of logistics enterprises have mostly focused on the integration of third-party logistics and related fields (e.g., Zaheer et al., 1998 [10]; Luo et al., 2015 [11]; and Wang et al., 2009 [12]), largely overlooking trust issues at the crowdsourcing level [9]. Some studies have discussed the impact of trust on crowdsourcing performance from the perspective of the overall crowdsourcing environment (e.g., Yao et al., 2019 [7] and Ye and Kankanhalli, 2017 [9]), and very few have explored the impact of trust on operational performance particularly in crowd logistics. The trust issue between crowd workers and logistics companies has produced a slew of social problems. There is also a study on this topic gap. Therefore, our study motivation is to make up for this gap in the literature and provide practical implications for crowd logistics participants. The questions to be tackled in this paper are: how does logistics synergy and trust between crowd workers and crowdsourcers impact the operational performance of the crowd logistics enterprise? On a micro level, resolving this issue aids in enhancing the synergistic efficiency of the crowd worker and the enterprise; on a macro level, it promotes the long-term development of urban logistics.

This study addresses some of these research oversights. To ensure the depth of analysis, this study focuses mainly on physical crowd logistics. By applying theories in commitment, trust, and logistics synergy, a research model was developed exploring the impact of trust and the mediating role of logistics synergy on enterprises' operational performance. The main contribution of our research is the construction of a theoretical model of the relationship between trust and crowd logistics enterprise's operational performance. The results of this study can help promote cooperation between the enterprises and crowd workers, improve operational performance, and enhance the service level of crowd workers. Customers, meanwhile, can profit from increased trust between crowd workers and businesses. Because crowd workers who have a high level of trust may be better able to follow delivery standards and preserve the privacy and information of clients. Thus, the practical value of our study is that our research findings may benefit crowd workers, crowdsourcers, customers, and crowdsourcing platforms.

The rest of the paper is arranged as follows. Section 2 is the literature review, while Section 3 provides the theoretical background and research hypothesis. Section 4 discusses the research method and empirical results. Section 5 presents the discussion of results, while Section 6 provides the conclusion, limitations, and future research directions.

2. Literature Review

2.1. The Origin and Role of Trust. Trust, which refers to an individual's dependence on a partner in the presence of risk, first appeared in the field of psychology [10] and was later applied in relationship marketing research [13]. With the growth and expansion of the market economy, trust issues between enterprises have become more prominent, and research on trust has grown significantly. For example, McAllister [14] divided trust between organizations into cognitive and affective. He defined cognitive trust as believing that the other party has enough ability, including technology, capacity, and knowledge, to achieve the desired results. Affective trust emphasizes the emotional interaction between two parties, focusing on the duration of cooperation when the external environment fluctuates and is driven by emotions and relationships [14]. Inkpen and Tsang [15] pointed out that trust is crucial in organizational relationships and is an important predictor of organizational performance. Fynes et al. [16] concluded that trust between enterprises could reduce opportunistic behaviors in both parties and reduce transaction costs.

In recent years, the relationship between trust and enterprises' operational performance has been the focus of numerous studies. Many scholars have explored the promoting effect of trust on enterprise operational performance from the perspective of third-party logistics integration (e.g., Hofer et al., 2009 [17]; Lai et al., 2013 [18]; and Dai et al., 2015 [19]). Studies have found that the trust between logistics outsourcing enterprises and service providers can promote integration among third-party logistics and boost the operational performance of logistics enterprises [17, 18]. Developing trust between partners would reduce erratic and uncertain behaviors, reduce supervision costs for both parties, and improve operational performance [19]. The positive effect of trust has been proven to be effective in internet technology (IT) outsourcing enterprises and enhance innovation among enterprises [20, 21].

For crowdsourcing, Blanchard and Markus [22] found that trust in the crowdsourcing platform affects participation behavior, impacting crowdsourcing performance. Similarly, Bauer et al. [23] concluded that trust has an important influence on participants' online social behavior. Norat [24] pointed out that increasing trust among crowd workers is conducive to the continued completion of tasks, reduces the number of abandoned packages in the distribution process, and improves crowdsourcing performance. Analyzing the relationship between trust and crowdsourcing performance, Meng [25], Tu [26], Pang [27], and Yao et al. [7] found that the degree of mutual trust among principal parts (e.g., crowd worker, enterprises, and platforms) can, directly and indirectly, impact crowdsourcing performance.

2.2. Trust in Crowd Logistics. The crowdsourcing operation mode is based largely on the concepts of the sharing economy and open distribution and is driven by the emergence of smartphones, global positioning system (GPS), WLAN, and information and communication technology. This operation mode has been absorbed by the logistics field [6], resulting in a new group of crowdsourcing logistics enterprises (e.g., JD-dada, FlashEx, and MyWays). While some have argued that scholarly research on crowd logistics has significantly lagged behind its current practical applications [28, 29], a number of studies have been conducted investigating particular aspects of crowd logistics. For example, Chanal [2] argues that crowd logistics can be used to tap idle social resources to solve distribution needs and mitigate shortages in human resources. Carbone et al. [29] believe that crowd logistics can make full use of people's idle time, abilities, and other logistics resources to develop logistics services. Wang et al. [30] proposed applying crowd logistics to solve the last-mile delivery problem, realizing the optimization of real-time logistics distribution. Lin et al. [31] argue that crowd logistics has the advantages of low distribution costs and environmental friendliness.

Numerous scholars have also researched the influencing factors, behavioral decisions, and legal governance issues of crowd logistics. For example, from the perspective of crowdsourcer, Bin et al. [32] explored the main factors influencing the implementation of crowd logistics and concluded that logistics operation mode, external incentives, internal benefits, and security of transformation significantly affect the willingness of enterprises to implement crowd logistics. Liang et al. [33] built a theoretical model, studying the effects of participation motivation, subjective norms, perceived behavior, and satisfaction on crowd workers' continued participation. Guo and Wang [34], using the theory of UTAUT (unified theory of acceptance and use of technology), applied a structural equation model to empirically analyze the influencing factors of crowd workers' participation behavior in crowd logistics. Sun et al. [35] identified risk factors in crowd logistics through literature research and used Fengniao (a crowd logistics application) to conduct an empirical analysis on factors affecting consumer satisfaction. Peng [36] studied the multiple legal risks in crowd logistics and made recommendations, including the establishment of a credit system and information protection mechanisms.

Most studies on crowd logistics largely involve concept definitions, influencing factors, behavioral decisions, and the positive effects of the new logistics mode. Few have explored its negative effects (see Mladenow et al. [6] for a notable exception). Although the current research on crowd logistics involves identifying risk factors, few have analyzed trust and its associated risks generated in this process (see Huang et al. [37] for a notable exception). In particular, how trust between the crowd worker and the logistics enterprise can be further encouraged requires further investigation. In third-party logistics, trust is considered a pivotal factor in enhancing the operational performance of enterprises. However, the cooperative relationship under the crowd logistics mode is generated based on the task, with short timelines, weak stability, and poor sustainability. Building trust between the crowd worker and the crowdsourcer and promoting cooperation and synergy are critical to reinforcing the operational performance of crowd logistics enterprises.

3. Theoretical Background and Hypothesis

3.1. Theoretical Background

3.1.1. Commitment-Trust Theory. Commitment-trust theory is a fundamental theory in relationship marketing. It was first proposed by Morgan and Hunt and is regarded as an important mechanism to promote customer relationships [13]. According to Morgan and Hunt, commitment and trust are crucial to competitive advantage. Trust determines commitment. It can push the customer to rely on the transactional relationship with the marketer and be willing to make a personal effort to maintain that relationship. The relationship capital between trust and commitment also helps reduce misunderstanding and customer concerns on particular uncertainties and transactional risks [13].

In recent years, this theory has been applied in numerous management studies. For example, Zhu [38] applied commitment-trust theory to empirically analyze the influence of trust on user participation in social media. Yao [39] verified that trust has a positive impact on supply chain performance through the mediating role of synergy. Cui et al. [40] also used this framework to study the influence of trust on online participation willingness and satisfaction in cross-border mobile commerce. These studies show that the commitment-trust theory provides a positive theoretical reference to study participatory behavior in the sharing economy. Since trust is crucial between the crowd worker and the crowdsourcer in the crowd logistics network, we used this theory to explore the influence of trust on the crowd logistics enterprises' operational performance.

3.1.2. Logistics Synergy Theory. Logistics synergy was first analyzed in the United States and has since been studied from different perspectives. Sacaluga [41] posits that logistics synergy mainly refers to the efficient and coordinated operation among various functions, including logistics, to maximize customer demand. Cao and Yang [42] studied the influence of supply chain synergy on enterprise performance. Chen et al. [43] expounded the necessity of enterprise knowledge chain innovation and forwarded corresponding innovation countermeasures using the logistics synergy theory. Zhang et al. [44] applied this theory to the coordinated development mode of rural e-commerce and rural logistics. Based on this theory, Zhang [45] constructed the cross-border e-commerce and cross-border logistics synergy mode and raised a series of measures to promote the value of enterprises. With the continued application of this theory, logistics synergy has increasingly presented the trend of interdisciplinary sharing.

Crowd logistics is mainly supported by internet information technology, where enterprises outsource delivery tasks to the public [6]. The two parties cooperate to share logistics information, technology, and human resources, thus increasing resource allocation efficiency, reducing logistics costs, and enhancing enterprise performance. Crowdsourcing system includes not only enterprises, platforms, and crowd workers but also information, capital, human resources, technology, and other resource elements [37]. Since the synergy of elements within the system has a significant impact on crowdsourcing performance, we first discuss the theory of logistics synergy in studying crowd logistics enterprises' operational performance.

3.2. Research Model Construction. We separate the factors affecting the operational performance of the crowd logistics enterprise into trust (goodwill trust and ability trust) and logistics synergy using commitment-trust theory and logistics synergy theory. We propose that goodwill trust, ability trust, and logistics synergy can significantly impact crowd logistics enterprises' operational performance and that logistics synergy plays a mediating role on goodwill trust and ability trust in affecting operational performance. On this basis, a theoretical research model is developed and is presented in Figure 1.

3.3. Hypotheses. Based on literature review and theoretical analysis, this study presents several hypotheses on the relationship between trust, logistics synergy, and crowd logistics enterprises' operational performance.

3.3.1. Trust and Crowd Logistics Enterprises' Operational Performance. Trust is considered the foundation of effective cooperation [46]. Trust between enterprises can reduce opportunistic behaviors to maintain long-term benefits with existing partners and obtain specific performance results [47]. Early studies on the integration of third-party logistics found the role of a solid, trusting relationship as crucial in elevating the operational performance of logistics enterprises [17, 18]. Feller et al. [48] concluded that trust is a critical factor affecting the crowd worker's continued participation and can also determine crowdsourcing success. Bauer et al. [23] also found that trust affects the crowd worker's social behavior. Norat [24] further pointed out that enhancing users' trust in crowdsourcing enterprises can boost the enterprises' operational performance.

Trust can be divided into different dimensions in various ways. In this study, trust is divided into two dimensions, based on the studies of Jonathan and Kankanhalli [9], McAllister [14], and Mayer et al. [48]: goodwill trust and ability trust. In the sharing economy, the demand side is largely concerned with whether the resource supplier has the skills and ability to meet its needs and whether it has essential qualities of kindness and integrity [49]. Numerous scholars (e.g., Meng and He, 2020 [49]; Wang, 2011 [50]; Li and Yu, 2011 [51]) have found that ability trust and goodwill trust are key factors driving consumer's behavioral intention in the sharing economy.

In goodwill trust, the enterprise believes that the crowd worker can keep the qualities of honesty and trustworthiness amidst fierce market competition, safeguarding the company's interests [49]. Goodwill trust focuses on the sense of moral obligation and responsibility, which can significantly impact the individual's attitude and behavior and affect the performance of enterprises [50]. Goodwill trust focuses on the quality and intentions of partners, which are conducive to reducing transaction costs and opportunistic tendencies and raising the stability of cooperative behavior and the operational performance of supply chain enterprises [51].

Crowd logistics adopts the idea of the sharing economy in its operation mode, maximizing idle labor resources to perform urban logistics services. However, in actual practice, the loose cooperative relationship between crowd logistics enterprises (crowdsourcer) and the crowd worker is highly uncertain [52]. Crowd workers, for example, are often penalized by companies due to complaints from consumers. When receiving first-time complaints, enterprises often forego investigation and directly blame the crowd worker, at a time when goodwill and trust have not been formed between the two parties. This behavior reduces enthusiasm among crowd workers to participate in crowd logistics, affects their service quality, and adversely impacts the enterprise's operational performance. Accordingly, this study offers the following hypothesis:

> H1a: Goodwill trust has a positive impact on crowd logistics enterprises' operational performance

Ability trust refers to the enterprise's belief that crowd workers can achieve their own needs and expectations and perform their duties smoothly. In practice, delivery risks (e.g., vandalizing parcels and revealing customer information) are widespread, given the absence of professional training for crowd workers [53]. If the enterprise, as the demander, chooses to trust the crowd workers' professionalism that they will not harm the interests of the enterprise for their own interests, a healthy cooperative relationship can be formed between the parties, which will improve the performance of the enterprise. Morgan et al. [13] argue that ability trust helps partners not have to repeatedly explain each other's abilities, which helps promote high-quality cooperation, reduces unnecessary supervision and incentives, and advances the response speed of the supply chain. Therefore, the ability trust of the enterprises to connect with crowd workers can help increase their continued willingness and participation, significantly reduce management costs, and raise the company's operational performance. Based on these arguments, we put forward the following hypothesis:

> H1b: Ability trust has a positive impact on crowd logistics enterprises' operational performance

3.3.2. Logistics Synergy and Crowd Logistics Operational Performance. Synergy results from one party choosing to interact and cooperate with another, given the difficulties of accomplishing its goal by itself [54]. With the growing application of synergetics theory in various disciplines (e.g., economics and engineering), its use in logistics has also increased [55]. Research on logistics synergy mainly focuses on the supply chain, emphasizing cooperation between supply chain functions from multiple dimensions to maximize overall efficiency. Research has shown that logistics synergy in the supply chain positively affects the enterprise's operational performance and that strengthening information resource coordination among enterprises helps improve operational performance [56, 57]. Wang et al. [8] concluded that logistics synergy is a crucial factor affecting enterprise performance.

In crowd logistics activities, enterprises and crowd workers carry out flexible logistics synergy through advanced management and information technology to achieve common goals. The logistics synergy between the crowdsourcer and the crowd worker through the original boundary of enterprise capital specificity realizes cross-organization sharing and resource allocation. This synergy significantly boosts the operational flexibility of third-party logistics enterprises and improves the level of customer

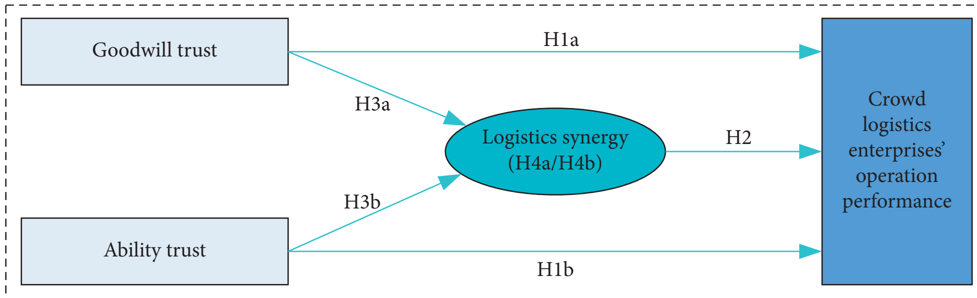

Figure 1: Research model.

service. This means logistics synergy is a critical force to promote the crowd logistics enterprises' operational performance. Hence, we propose the following hypothesis:

> H2: Logistics synergy has a positive impact on crowd logistics enterprises' operational performance

3.3.3. Trust and Logistics Synergy. Trust is the basis of effective collaboration and plays a positive role in promoting cooperation between enterprises [45, 58]. Crowd logistics offers delivery invitations to a large group of people in a collaborative way. In this process, trust between the crowd worker and the crowdsourcer may affect the logistics synergy. Saenz et al. [59] found that organizations that lack trust are more likely to reject logistics collaboration. Zhang et al. [60] found that trust is a critical factor that can restrict horizontal logistics synergy. In other words, enterprises that trust each other are more likely to carry out synergistic activities for particular logistics businesses [61].

In the crowd logistics system, the moral level of the crowd worker is a major factor for enterprises to measure synergy. The goodwill trust of the enterprise recognizes that the crowd worker has a moral character of loyalty and integrity and trusts the cooperative behavior of each other [62]. Therefore, we propose the following hypothesis:

> H3a: Goodwill trust has a positive effect on logistics synergy

Ability trust encourages enterprises to believe that crowd workers have the strength and ability to complete the task and achieve the targets. This enhances information sharing and promotes cooperative behavior between parties, further improving the degree of synergy [63]. Crowd logistics enterprises pay attention to service quality and delivery efficiency and are likely to choose qualified, competent, and experienced crowd workers [7]. This kind of ability trust can help enterprises reduce synergy costs and enhance crowd logistics synergy with crowd workers. Hence, we propose the following hypothesis:

> H3b: Ability trust has a positive effect on logistics synergy

3.3.4. The Intermediary Role of Logistics Synergy. Trust can be a significant factor restraining opportunistic behavior and promote the development of synergistic activities. Efficient synergistic activities have been shown to reduce operating costs and improve customer service quality [16]. In the crowd logistics market, enterprises' trust in crowd workers can help reduce the need for formal contracts, decrease unnecessary logistics links, and increase logistics response speed [12]. Developing trust also promotes the transfer and sharing of information, technology, and other resources between crowd workers and crowdsourcers, thus lowering transaction costs and positively impacting operational performance. Based on these arguments, we propose the following hypotheses:

> H4a: Logistics synergy plays a mediating role in the influence of goodwill trust on crowd logistics enterprises' operational performance
>
> H4b: Logistics synergy plays a mediating role in the influence of ability trust on crowd logistics enterprises' operational performance

4. Research Methodology and Results

The research method of this paper consists of five steps: (1) questionnaire design, (2) questionnaire pretest, (3) data collection, (4) selection of control variables, and (5) data analysis [37, 64].

4.1. Questionnaire Design. The questionnaire consists of two parts. The first part includes the basic information of the crowd logistics enterprises, including the ownership, annual sales, and the number of years of operation. The second part consists of four latent variables: ability trust, goodwill trust, logistics synergy, and operational performance. The observation items for each latent variable were based on measurement scales developed and verified in previous studies and adjusted according to the practical background of crowd logistics. Table 1 provides the summary of latent variables and observation items used in the study. We used a Likert five-point scale to quantify each observation item ranging from: strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree [65].

4.2. Questionnaire Pretest. Before the actual survey, we pretested the questionnaire and sent it to 12 senior managers of crowd logistics enterprises by e-mail. The managers were from Changsha city, Zhuzhou city, and Xiangtan city. The

Table 1: Observation items for each latent variable.

Latent variables	Observation items	References
Goodwill trust (GT)	H1a-a1: I believe that when the market changes, the crowd worker will not be inclined to transfer costs to the enterprise H1a-b1: I believe that the crowd worker pays close attention to the needs of the enterprise and sincerely cares about the success of the enterprise H1a-c1: I believe that the crowd worker has sacrificed for the enterprise in the past	Levin and Cross [66]; Ganesan [67]
Ability trust (AT)	H1b-a2: I believe that the crowd worker has strong working skills, and working with them can enhance the enterprise's operational performance H1b-b2: I think most of the crowd workers are reliable in terms of their business capability H1b-c2: In my opinion, the crowd worker meets the task requirements of the enterprise and can complete the delivery task with high quality	Mcallister [14]; Anderson and Narus [68]
Logistics synergy (LS)	H2-a3: Our enterprise keeps regular feedback and communication with the crowd worker H2-b3：I think when the customer demand change, the enterprise and the crowd worker can negotiate to develop a flexible workflow H2-c3: To my way of thing, the enterprise and the crowd worker can share crowd logistics information in a timely manner	Sinkovic and Roath [69]; Story et al. [70]
Crowd logistics enterprises' operational performance (CLEOP)	H-a: In my opinion, crowd logistics enterprises can provide excellent customer service quality H-b: I think crowd logistics enterprises can respond to customer needs in a timely manner H-c: I think the delivery speed of crowd logistics enterprises is fast, and the delivery reliability is strong	Zhao et al. [71]

pretest was to identify possible errors, confusing statements, or ambiguous language in the questionnaire. The work took two weeks to finish and was conducted in August 2020. Based on the feedback, modifications were made accordingly.

4.3. Data Collection. The respondents to the actual survey were senior managers of crowd logistics enterprises from the cities of Changsha, Zhuzhou, and Xiangtan in Hunan Province, China. These cities form the "Chang-Zhu-Tan Urban Agglomeration" (see Figure 2). In 2007, the urban agglomeration was approved by the State Council as a national comprehensive reform pilot area for resource efficiency and environment friendliness [72]. Adhering to the concepts of green and shared development, this urban agglomeration has been encouraging crowdsourcing business development in recent years. Crowd logistics is characterized by both sharing and green development [6], and thus, this business mode has been strongly supported by the local government.

The survey was conducted both offline and online (via e-mail, WeChat, and other social software) and was conducted for nearly 3 months, from September to November 2020. On average, the respondents were able to finish the survey in about 7 minutes. While we did not offer material rewards to the respondents, we promised that the participating enterprises would be given priority to cooperate with our team in future logistics experiments and studies. This was received positively by many crowd logistics enterprises. Among the 63 questionnaires sent out, 56 were recovered, equivalent to an overall recovery rate of 88.9%. Fifty questionnaires were valid, resulting in an effective recovery rate of 89.3%. The characteristic distribution of valid sample enterprises is shown in Table 2. In terms of ownership structure, private enterprises accounted for 64.36%, while state-owned enterprises accounted for 23.27%. More than 90% of the sampled enterprises have been operating for more than 10 years, and nearly 60% have annual sales of more than 100 million yuan.

4.4. Selection of Control Variables. The factors that remain unchanged or are not evaluated during the experiment are referred to as control variables [73]. To eliminate the potential influence of certain factors, we used some basic information on the respondent's enterprise as control variables. These include the ownership structure of the enterprises, the number of years it has been in business, and its annual sales. The control variables used in this study are listed in Table 2.

4.5. Data Analysis. Partial least squares (PLS) [74] structural equation modeling was used for data analysis and hypotheses testing. PLS is a component-based estimation method widely used in social science research to analyze quantitative data [75]. Compared with LISREL, AMOS, and other methods, PLS is more applicable for quantitative analysis of structural equations with small sample sizes and can process non-normally distributed data samples and test higher-order structural equation models [76]. In this paper, trust was used as a second-order latent variable, and PLS modeling can more accurately reflect the relationship between higher-order model variables. Furthermore, trust

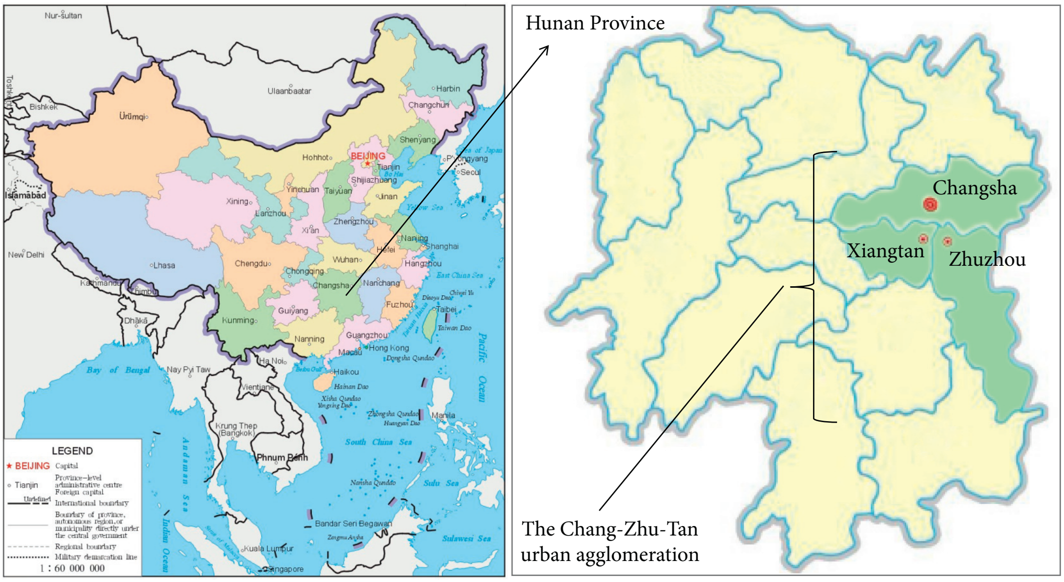

Figure 2: The cities where the data were collected.

Table 2: Descriptive statistical information of crowd logistics enterprises.

Category	Item	Ratio (%)
Ownership structure	The private enterprise	64.36
	Wholly foreign-owned enterprise	4.47
	Sino-foreign joint venture	7.90
	State-owned enterprises	23.27
Business years	< 10 years	9.41
	10–19 years	37.62
	≥20 years	52.97
Annual sales (yuan, CNY)	< 1 million	1.98
	1 million–5 million	4.95
	5.01 million–10 million	1.49
	10.01 million–50 million	6.44
	50.01 million–100 million	25.25
	≥100 million	59.9

between crowd workers and logistics companies is difficult to assess in the usual sense. SEM-PLS is well suited to analyze survey data in such complicated scenarios [76].

4.5.1. Reliability and Validity Tests. Reliability and validity tests are used to verify whether the measured scale is scientific [74]. In this study, Cronbach's alpha (CA) and average variance extracted (AVE) values were used. The lowest CA value was 0.814 (≥0.7), and the lowest CR value was 0.889 (≥0.7), indicating good reliability in the study's scale design [77]. The outer loading values for all observed variables were greater than 0.7 (the minimum is 0.807), as shown in Figures 3–5. The calculated AVE values were greater than 0.7 (the minimum is 0.729), as shown in Table 3, indicating that the indicator data had good convergence validity [77]. In addition, the AVE square root was greater than the correlation coefficient between latent variables. This suggests no collinearity among the latent variables and good discriminative validity for the model (as shown in Table 4) [77].

Considering that common method bias (CMB) may adversely affect the results of the study [78], a method of procedural control was used [46]. We first conducted a pretest before the formal questionnaire survey, which eliminated the problems caused by semantic deviations or difficulty of respondents to understand the questions. Then, we informed the respondents before the survey that their personal and business information will be kept confidential throughout the study [37].

4.5.2. Hypothesis Testing. Three models were constructed using SmartPLS3.0 software to analyze the following: the influence of goodwill trust and ability trust on logistics synergy (model 1, see Figure 3); the influence of goodwill trust, ability trust, and logistics synergy on the crowd logistics enterprises' operational performance (model 2, see Figure 4); and the mediating role of logistics synergy in the process of trust influencing crowd logistics enterprises' operational performance (model 3, see Figure 5). The first two models were compared with model 3 to determine whether logistics synergy plays a mediating role.

In the three validation models, the minimum R^2 value was 0.667, indicating good explanatory ability for the constructed research model had [77]. Based on the results shown in Table 5, H1b, H2, H3b, H4a, and H4b passed the hypothesis test (p-value ≤ 0.05 [77, 79]), while H1a and H3a (the path coefficient is negative, contrary to our hypothesis) did not pass the hypothesis test (p-value > 0.05 [77, 79]).

4.5.3. Findings

(i) Confirmed hypothesis

The results suggest that ability trust positively affects the crowd logistics enterprises' operational performance (H1b passed the hypothesis test), similar to the

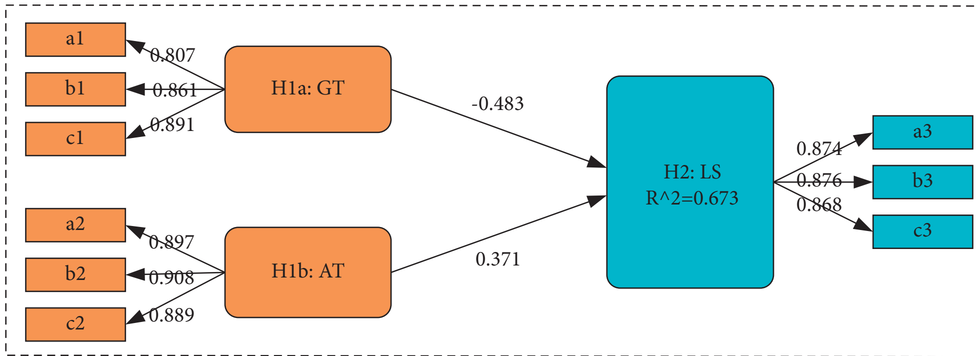

Figure 3: The model 1 results.

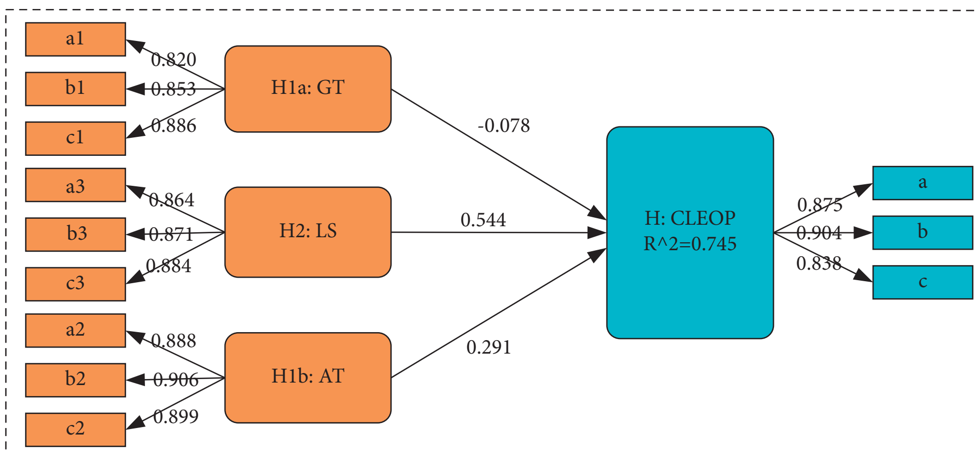

Figure 4: The model 2 results.

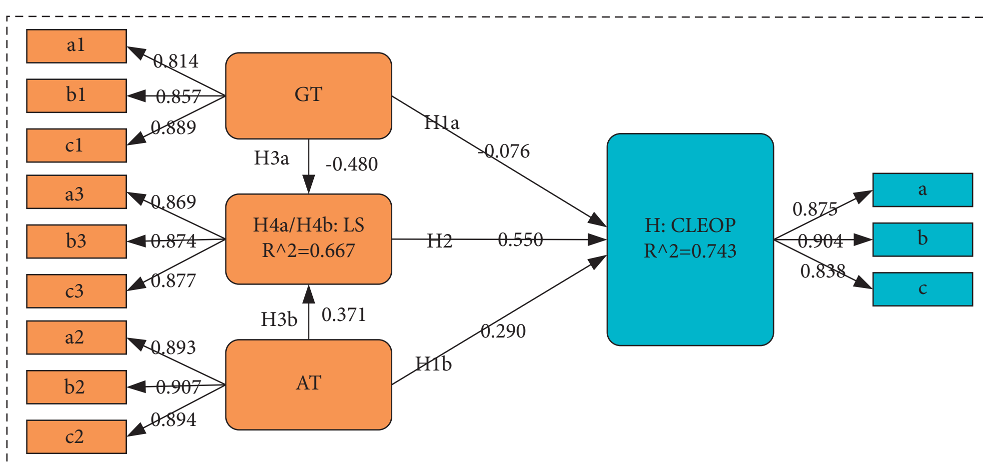

Figure 5: The model 3 results.

conclusions of some previous studies (e.g., Luo et al. [11], Hofer et al. [17], and Cheng et al. [80]). This means that if an enterprise has trust in its crowd workers' abilities to complete the delivery work, it will have a positive impact on the company's operational performance. Therefore, enterprises can improve the effectiveness of cooperative relationships and increase operational performance by developing and cultivating trust with their crowd workers.

Ability trust positively affects logistics synergy (H3b passed the hypothesis test). If the crowd logistics enterprise trusts that its crowd workers have the skills to complete the delivery task with high quality, it will help promote synergistic activities. Previous studies have

Table 3: Reliability and validity test results.

Latent variables	CA	CR	AVE
AT	0.880	0.926	0.806
GT	0.814	0.889	0.729
LS	0.844	0.906	0.762
CLEOP	0.844	0.906	0.762

Table 4: Average variance extracted (AVE) square root and factor correlation coefficient.

	H1a	H1b	H2	H
GT	**0.854**			
AT	−0.841	**0.898**		
LS	−0.792	0.774	**0.873**	
CLEOP	−0.755	0.780	0.835	**0.873**

Note: diagonal elements (the bold values) are the square root of average variance extracted (AVE).

Table 5: Results of hypotheses testing.

	Model 1			Model 2			Model 3		
Path	Path coefficient	*t*-value	*p*-value	Path coefficient	*t*-value	*p*-value	Path coefficient	*t*-value	*p*-value
GT⟶LS	−0.483	3.231	0.001				−0.480	3.282	0.001
AT⟶LS	0.371	2.205	0.028				0.371	2.256	0.024
LS⟶CLEOP				0.544	4.001	≤0.001	0.550	4.406	≤0.001
GT⟶CLEOP				-0.078	0.658	0.511	−0.076	0.699	0.485
AT⟶CLEOP				0.297	2.254	0.025	0.290	2.206	0.028

confirmed the positive effect of trust on synergy. For example, Wang et al. [8] found that mutual trust between suppliers and crowd workers can enhance their degree of synergy, provide enterprises with a competitive advantage, and help meet consumer needs.

Logistics synergy positively influences crowd logistics enterprises' operational performance (H2 passed the hypothesis test), and logistics synergy plays a mediating role in how ability trust positively affects operational performance (H4b passed the hypothesis test). This conclusion is similar to the findings of Erik [56] and Frank et al. [57]. Lu and Gao [81] believe that a good synergistic relationship between employees and enterprises is crucial for the success of supply chain operations. When traditional logistics enterprises carry out promotional activities on various e-commerce platforms, they often face multiple problems, such as overcrowded express warehouses and insufficient transport capacity. Through logistics synergy with crowd workers, enterprises can promptly share workforce, logistics, information, and other resources. This considerably reduces the costs of purchasing special delivery vehicles and recruiting formal employees. And with timely feedback, this system can flexibly respond to the fluctuations in customer needs, greatly improving service quality and customer satisfaction. The results show that ability trust not only affects the enterprises' operational performance directly but also has an indirect effect through the intermediary variable of logistics synergy. To promote the positive effect of ability trust in operational performance, logistics enterprises should build a good synergistic relationship with their crowd workers and regularly implement synergistic activities.

The results also show that logistics synergy plays a mediating role in how goodwill trust affects operational performance (H4a passed the hypothesis test). The results show that logistics synergy amplifies the inhibitory effect of goodwill trust on operational performance, which may be caused by the maturation of the crowdsourcing market and the increasing diversification of crowd workers. In the sharing of information, technology, and resources, goodwill trust between enterprises and crowd workers can be established relatively quickly. This trust may lead to a relaxed environment for synergy, leading crowd workers to take advantage and have opportunistic behaviors. These outcomes would not be conducive to the improvement of the crowd logistics enterprises' operational performance.

(ii) Unconfirmed hypothesis

Goodwill trust was found to have no significant effect on the crowd logistics enterprises' operational performance (H1a did not pass the hypothesis test). This conclusion is similar to the findings of Ganesan [67]. One possible explanation for this finding is that enterprises are mainly concerned with task completion when selecting crowd workers. Goodwill trust depends largely on the quality and intentions of partners and is a soft resource that gradually develops over long-term communication and collaboration. Since crowd workers are external temporary hires, enterprises are not compelled to have long-term communication, mutual familiarity, and identification. Moreover, goodwill trust is not as easily perceivable as ability trust. These could explain why goodwill trust did not significantly affect the operational performance of crowd logistics enterprises.

Goodwill trust negatively affects logistics synergy (H3a did not pass the hypothesis test), which is contrary to the research hypothesis of this paper. In most cases, the goodwill trust of the enterprise to the crowd worker can only be obtained by short-term emotional perception, which can easily lead to subjective wrong judgment. Some crowd workers who do not have the goodwill quality enter the enterprise, while some with excellent qualities are unjustly expelled from the market. If this goes on for a long time, the wrong goodwill trust cannot support the continuous development of logistics synergy between the two parties. Besides, in the absence of legal contracts, the crowd worker may take opportunistic behavior in the complex external environment, for example, the disclosure of some hidden, critical, and valid information (e.g., consumer's address and preference) shared by the enterprise. This will seriously violate consumer privacy and reduce customer satisfaction. Therefore, it may inhibit the positive effect of logistics synergy.

5. Discussion

In this paper, we proposed a total of seven research hypotheses, five of which have been verified. These five hypotheses are about the impact of trust on the crowd logistics enterprises' operational performance. The findings suggest that ability trust and logistics synergy are significant variables that directly impact crowd logistics enterprises' operational performance. Ability trust is positively correlated with logistics synergy; the more ability-trust logistics enterprises have in the crowd workers, the more conducive it will be to the collaborative operation of logistics enterprises. Logistics synergy was also found to play a mediating role between trust (both goodwill trust and ability trust) and operational performance. These findings largely support the conclusions of existing literature. These findings are similar to those of some previous studies (e.g., Ye and Kankanhalli, 2017 [9] and Huang et al., 2020 [37]), and we expect that these findings will be echoed in other contexts. The following are some theoretical and practical implications based on the results of this study.

5.1. Theoretical Implications. First, this study adds to the growing literature about the role of trust in crowd logistics. Crowd logistics has become a major research topic, with numerous studies being conducted from varying perspectives. For example, studies have been made analyzing the influencing factor affecting continued participation in crowd logistics, from the perspective of crowd workers (e.g., Ye and Kankanhalli [9], Liang et al. [33], and Huang et al. [37]). Several studies have investigated the influencing factors of implementation from the perspective of enterprises or platforms (e.g., Yao et al. [7], Bin et al. [32], and Bin et al. [64]). Some have explored the environmental sustainability of crowd logistics (e.g., Mladenow et al. [6], Rai et al. [28], and Lin et al. [31]). This paper focuses on the issue of trust, which provides a new insight for establishing a good cooperative relationship between the enterprise and the crowd worker.

Second, this study comprehensively investigates the impact of logistics synergy on the operational performance of crowd logistics enterprises. The perspectives of crowd workers and crowd logistics enterprises are taken into account and integrated into a theoretical model and analysis, as well as factoring in the effects of logistics synergy [41]. The addition of logistics synergy factors significantly improves the discussion on the relationship between the crowd worker and the enterprises, providing new insights into the subject matter.

Finally, this paper expands the application of commitment-trust theory in crowd logistics research. Informal cooperation between the crowd worker and the crowd logistics enterprises requires more trust to maintain the relationship between the two parties. This suggests that this theory can be used and expanded to other related disciplines (e.g., Zhu [38], Yao [39], and Cui et al. [40]). In particular, there is no legal, contractual relationship between the two parties.

5.2. Practical Implications. First, enterprises and platforms should scientifically evaluate the abilities of crowd workers and promote trust relationships with crowd workers. The results show that ability trust has a significant positive impact on the operational performance of crowd logistics enterprises. Therefore, enterprises should establish an assessment method in selecting experienced and skilled crowd workers to ensure that the crowd worker can fulfill their work on time [37] and provide high-quality delivery service [32]. Enterprises should also construct a personal credit system and a service quality evaluation system in their operations and adopt an elimination system for crowd workers with low distribution efficiency, high credit risk, and poor service levels. These measures can help enterprises reduce their distrust against opportunistic behavior when the environment is changing or unpredictable (e.g., the emergence of peak orders and the appearance of bad weather).

Second, enterprises should strengthen crowd logistics mechanisms that enhance synergistic efficiency. The results show that logistics synergy is a significant mediating variable increasing the operational performance of enterprises. In crowd logistics, enterprises and crowd workers have broken through the traditional boundaries of enterprise capital specificity, raising higher requirements on cross-organizational sharing, resource allocation, and collaborative logistics operations [6, 28]. Therefore, enterprises should maintain open communication with their crowd workers, sharing timely internal and external logistics information and quickly responding to changes in the external environment. Building sound information feedback and sharing mechanism is essential to ensure that logistics information can be sent and received accurately, timely, and efficiently and raise the speed and reliability of delivery services.

Finally, enterprises should invest in skills training for crowd workers. This study found that most crowd workers registered on the crowdsourcing platform are part-time personnel who have not received standardized professional training. This has resulted in the uneven quality of services, affecting enterprises' operational performance [6]. Enterprises should conduct systematic training for part-time staff, particularly those involved in crowd delivery operations [37]. Enterprises should also regularly carry out skills development on safety management and risk prevention and provide other relevant training to their crowd workers to improve their professional skills and minimize risk concerns.

6. Conclusions

With the emergence of the sharing economy, huge demands for logistical services have created the distribution mode of crowd logistics [82]. In route selection and optimization, the use of information communication, satellite location, and navigation provides crucial technical support for the development of crowd logistics. Trust and synergy between crowd workers and the crowdsourcer, however, have become essential challenges in the growth and development of crowd logistics in day-to-day operations. To address some of the current knowledge gaps on the subject matter, this study analyzed the impact of trust between crowd logistics enterprises and crowd workers on operational performance and integrated logistics synergy into the theoretical model. The results indicate that ability trust and logistics synergy are significant variables, directly increasing the operational performance of crowd logistics enterprises. Ability trust was also found to be positively correlated with logistics synergy. The results also show that logistics synergy plays a mediating role between trust (both goodwill trust and ability trust) and operational performance. This work focuses on the examination of the trust relationship between the crowd worker and the crowdsourcer, which is beneficial to promoting the sustainable development of urban logistics.

Based on the results, we recommend that logistics enterprises and platforms evaluate their crowd workers' capabilities and promote trust relationships with them. Enterprises should strengthen crowd logistics mechanisms that stimulate collaborative efficiency. Enterprises must invest in training and developing their crowd workers to boost their abilities and encourage trust, which would eventually enhance their operational performance.

There are some limitations to this study. First, the conclusions may have some regional characteristics. The study area was the Chang-Zhu-Tan urban agglomeration, and some of the results may have been affected by local factors. Future studies can focus on other regions and other scales and compare the results of this study. Second, this paper focused on the influence of trust on operational performance and did not consider other factors that could have affected the results, such as incentive mechanisms and satisfaction. Future research should consider the impact of other factors on the operational performance of crowd logistics enterprises. Third, the commitment-trust theory and logistics synergy theory are applied to this study. Different theoretical foundations may necessitate different factors to be examined, and additional research would be required. Fourth, this study surveyed mainly senior managers. Future studies should consider surveying crowd workers and compare the results of this study. Finally, as part of the industry 4.0 development process, we must continue to pay close attention to and investigate the relationship between crowd workers and logistics companies. Crowd workers are mostly managed by platform algorithms rather than actual managers in the context of the rapid growth of computer algorithms. Therefore, how enterprises handle the balance between managers and platform algorithms has a big impact on how crowd workers and logistics companies trust each other.

Data Availability

If interested scholars have data requirements, please contact the second author by e-mail (xiaox3731@gmail.com).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Optimization of Hybrid Multimedia Art and Design Teaching Mode in the Era of Big Data

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In this paper, a 9-layer convolutional neural network with 4 convolutional layers, 4 pooling layers, and 1 fully connected layer is designed to recognize the emotions of digital learning images in the era of big data. The convolutional neural network is trained using digital learning images that have been labeled with emotions, and the final test shows that the network has good recognition results. This in turn causes the information overload problem to arise. And combined with the questionnaire results and interviews, it was found that there are problems of technology for technology's sake, teaching for teaching's sake, and in multimedia teaching, and these will add to the psychological and visual sensory burden of students and easily cause the information overload problem. The types of information overload problems in multimedia-assisted teaching are summarized as follows: unreasonable presentation of information, which causes audiovisual redundancy; too much teaching irrelevant information, which increases the external cognitive load; and an uncoordinated audiovisual environment, which increases the external cognitive load. Starting from the perspective of the integration of preservice to in-service art teachers' new media art curriculum design and teaching ability development, three representative teacher education cases were studied using a combination of teaching practice and case tracking methods to summarize the successful experiences and effective ways of art teachers' new media art curriculum development and teaching ability development, which will provide future art teacher training and in-service teachers' professional development. Both are below 5%. The types of funny emotions are mainly distributed in animation teaching methods. Animation resources are generally well designed in color and layout and can convey good visual emotional characteristics. In other types of images, the emotional distribution level of funny is less than 10%. It is worthwhile to learn from this experience.

1. Introduction

After entering the era of big data, human beings will face more impacts between big data and culture, artificial intelligence is developing rapidly, the world culture, technology, and art are facing new challenges, and images are flooding our lives like never before. However, the private demolition of cultural and historical buildings to build mansions, the piracy of famous Parisian architectural communities, the construction of rehashed Egyptian pyramids, and the placement of indecent public sculptures, all these ugly cultural images reflect the lack of people's aesthetic level, cultural respect, and creative consciousness, repeatedly becoming an obstacle to the development of civilization [1]. The development of civilization cannot be reduced to the sacrifice of science and technology. The aesthetics and inner cultural beliefs of human beings are the important force of the development of the times. In contrast, the current situation of art museum education in China is that art museum education activities are in various forms, but they lack the depth and extension of education and do not play a role in improving the visual literacy of citizens [2]. This study aims to explore the current situation of art museum education, understand the impact of art museum education on students' visual literacy, explore how art museum education should promote the improvement of students' visual literacy in the context of the big data era, cultivate a generation of citizens with good artistic cultivation, and promote the development of a generation of civilization progress [3]. The advent of the big data era has exposed a large amount of information to life, impacting modern human attitudes of thought and visual perception. Two hot zone comparison pictures with very strong synthesis, very weak sequence type, very weak synthesis type, and very strong sequence type are referred to as comprehensive type and sequence type hereinafter. The large volume and varying quality of information affect human cognition while testing modern humans' discernment and aesthetic ability of current information. The rapid development of social civilization is often hindered by the level of human's aesthetic cognition, such as the out-of-place urban sculptures and the high ratings of vulgar films and TV shows, which reflect the lack of quality of life and the pursuit of "beauty" in the current impetuous and fast life of human beings. This is the downside of the rapid development of material civilization and the difficulty of the public's visual literacy and civilizational awareness to keep up with the development of civilization.

The rapid development of information technology has not only revolutionized our work, study, and life but has also had a profound impact on the field of education and teaching, greatly contributing to the improvement of the efficiency of teaching and learning in schools [4]. In recent years, the way of teaching and learning in schools has also undergone major changes with the advancement of technology. With the continuous reform and innovation of technology, we have achieved a change from the early days of using audiovisual and auditory media such as slide projectors, video visualizers, tape recorders, radios, and other teaching devices to the present-day application of interactive whiteboards, multimedia computers, and network teaching platforms. The application of these devices and related teaching software in teaching has not only changed the effect of face-to-face teaching but also made it possible to realize distance network teaching across the limitation of space and distance. Based on the characteristics of the Internet itself, online network teaching is more informative, richer in learning resources, and more interactive in real time [5]. The comprehensive learning style is more interested in graphic information. When studying, he can integrate graphic information more closely, and the reading time is shorter. Participants with strong sequence type basically followed their logic when reading text. And with the continuous advancement and innovation of artificial intelligence, big data, cloud computing, and other information technologies, the impact of technology on the traditional classroom and changes to the field of education will grow, thus benefiting more schools and teachers and students [6]. Special emphasis is placed on the important role of the modern media arts curriculum in developing students' core literacy in the subject. Accordingly, how to give full play to the teacher's role in achieving effective teaching and better development of subject core literacy within the limited class time also becomes an important issue that must be properly addressed in teaching. In this study, the author tries to put the unit teaching "zero into whole" design concept throughout the modern media art course and strives for more focused teaching objectives, more optimized teaching content, and more comprehensive student abilities [7].

In today's booming modern information technology, the human scientific process is developing at an unprecedented speed, and the power of increasingly advanced information technology for film and television art is also more profound. As the seventh category of art, film and television art is different from painting, music, theater, and other ancient art forms, it has been accompanied by the process of science and technology since its birth, and film and television have a high degree of integration with modern information technology and tacit understanding. Modern information technology has pushed film and television art to take a big step towards industrialization, and it is also under the high degree of integration and interaction between information technology and film and television art that digitalization, virtualization, high speed, technology, specialization, and internationalization of film and television art have been realized, and information technology has had a profound impact on the creation, dissemination, and consumption of film and television, as well as on the aesthetics of film and television. This is the most favorable era for the development of the film and television industry, and modern information technology is also in the era of becoming the strongest development, which is the best era in human history, but at the same time the worst era. Under the influence of modern information technology, does film and television art grasp the most essential form of realization of film and television art? Without the help of modern information technology, will film and television art lower its level, or even lose its audience and box office? Film and television art as the seventh category of art forms has been in the form of cutting-edge and rapid performance. As the audience, we are undoubtedly experiencing great changes, and this change is also happening under the influence of modern information technology. The closer the combination of the two, the greater the mutual force will be. The content of both sides is constantly changing, the form is changing as well, and the audience's experience is also changing. The film and television art both technically and artistically has produced great fluctuation and impact.

2. Current Status of Research

Research on blended learning is much earlier abroad than at home. At present, the research on blended learning is mainly reflected in the concept and how it is applied. It is a local theory born and grown in China, and the research is still in the initial stage [8]. After the theory was proposed, a seminar on multimedia picture language was held at Tianjin Normal University. Since picture art design before that mostly applied to other disciplines of art theories, Lande et al. proposed a multimedia picture language art theory, which solved the problem of borrowing other disciplines of art theories [9]. After that, Li combined multimedia picture art theory with cognitive psychology to study the cognitive law of multimedia picture language and explored the cognitive law that should be followed in the design of multimedia teaching resources [10]. Patel and Sharma further developed multimedia picture language in "Research on the Construction of the Theoretical System of Multimedia Picture Linguistics," drawing on other linguistics, psychology, educational technology, and other related achievements, which provides a reference for multimedia picture language subsequent research providing a referenceable research framework as well as ideas and methods [11]. The strategy emphasizes three major educational resources, namely, educational policy and planning, teacher development and information and communication technology, and four priority development areas, namely, literacy, vocational and technical education and training, higher education, and learning process and outcome enhancement, and three major learning activities, namely, global citizenship education, education for sustainable development, and health education, intending to promote quality and comprehensive lifelong learning and thus fostering creativity and responsibility [12]. How to use multimedia to facilitate human learning is a central question in the study of multimedia learning. Ramsgaard Thomsen et al. divides the study and development of multimedia teaching and learning into two categories: the first category is technology-centered, and the second category is learner-centered [13].

Some foreign language colleges and universities began to have more advanced e-teaching equipment, such as simple language laboratories, and with the rapid development of e-education, e-education equipment was gradually applied to multimedia-assisted teaching. After entering the nineties, China's information technology developed rapidly, and since then, multimedia-assisted teaching has also been developed significantly. The research on multimedia teaching in this period is also more in-depth than that in the previous period, and there are researches on how multimedia teaching is used in specific subjects in colleges and universities and further analyses on how multimedia teaching is used in teaching practice [14]. 51.59% of the students said that the background color matching of the text in the multimedia courseware is relatively reasonable, which will not cause visual disturbance or redundancy, but 48.41% of the students said that the multimedia courseware has unreasonable places in the color matching; this will also disturb the learning and cause visual redundancy for students. Along with the increasing progress of education informatization, the use of multimedia-assisted teaching as a modern teaching tool has become increasingly common in the teaching of colleges and universities and has gradually become an important teaching tool in colleges and universities. The educational content in modern media art is provided, but it has certain problems, such as the prevalence of low attention, fragmented teaching content, single teaching method, fewer research results, and lack of relevant knowledge of teachers [15]. In response to these problems, this study uses literature method, questionnaire survey method, and comparative method to study the current situation and problems of the modern media art curriculum, and after analyzing the reasons, based on postmodern curriculum theory, constructivist teaching theory, theory of unified curriculum and interdisciplinary teaching, evaluation theory, multiple intelligence theory, and visual culture theory to compile and program design for new media art in secondary schools [16]. The birth and development of the art of cinema and the evolution of the art of cinema were accomplished in an integrated way with the role of technology: for the emergence and invention of the film camera and projector before the emergence of film as real art, due to technological improvements in the art of film and television added the element of sound, and the development of film technology contributed to the journey of color film, with the technology of film stunts, the Electricity Bureau could produce fantasy. The spectacle nature of cinema only then discovered, and cinema was further released on a deeper level.

In the context of a rapidly developing information society, the development of modern media art has grown rapidly and has fully penetrated all aspects of life, providing a favorable environment and excellent technology for the development of modern media art curriculum and teaching in schools. For the current generation of high school students, their social background and living environment have also resulted in greater interest and enthusiasm for digital products and video art than traditional art media, which is also an intrinsic motivation for the continuous development of modern media art learning modules.

3. Optimization Analysis of Hybrid Multimedia Art and Design Teaching Mode under Big Data

3.1. Multimedia Art Design Big Data Design. As one of the main manifestations of multimedia learning resources, the design of digital learning screens and their related research should be based on a theory that is consistent with human learning styles and should be explored and practiced in conjunction with the cognitive theory of multimedia learning. Richard E. Mayer of the University of California proposed a cognitive theory of multimedia learning based on three views of cognitive science and pointed out that multimedia-based learning activities should include three assumptions, namely, the dual-channel assumption, the limited capacity assumption, and the active learning assumption, to explain the cognitive tendency of learners when using multimedia resources for learning. The dual-channel hypothesis refers to the fact that people have separate information processing channels for materials with visual and auditory representations [17]. Paying attention to result evaluation, process evaluation is relatively lacking, and so on. The author also started thinking and researching and believes that modern media art curriculum learning evaluation tools should be developed, and learning evaluation dimensions should be established. In the evaluation, modern media art creation and appreciation capabilities should be integrated, and students should be clear that modern media art is not just creation of works. When visual information such as on-screen text and images containing knowledge, content is delivered to the learner's eyes, and the acquired information is processed in the visual-image channel; when narration, background music, and other information are presented to the learner's ears, the acquired information is processed in the auditory-verbal channel. Meyer argues that although the acquired information enters the information system through one channel, the learner can change the processing channel through a switch in representation. For example, when a learner looks at a text, he or she first represents the information through the visual-image channel, but a learner with the ability to read text can convert the information received through the visual into audio information, and the relationship between the two can be transformed through different representations.

The active processing hypothesis refers to the idea that learners actively engage in cognitive processing to build a coherent mental representation of their experience, meaning that learners' activities in processing multimedia information are active rather than passive. Meyer states that the three processes of active processing involve selection, organization, and integration. Selection means noticing multimedia information and creating discourse and picture material; organization means establishing intrinsic connections between the selected knowledge information; and integration means establishing extrinsic connections between the organized verbal model and image model and prior knowledge, thus facilitating meaningful learning to occur. Multimedia images should be composed in a way that is consistent with the subject matter to be represented and with certain artistry, like the art of speaking and presentation. Having a certain art is, for example, aesthetic, but more important is the effectiveness of its expression, which can be explored at the content level, the cognitive level, and the picture structure level in terms of its logical laws. Xiaofeng described the 12 multimedia design principles, which include the multimedia cognition principle, spatial proximity principle, time proximity principle, always principle, channel principle, redundancy principle, and personalization principle [18]. Thereby, this strengthened the harmonious interaction between learner's emotion and picture emotion in the smart learning environment. The coding of the digital learning screen can help users understand the attributes of the screen from the side. However, it is macrolevel, difficult to play a practical role, not yet able to solve the actual problems faced. Multimedia screen language has initially formed its unique design methods and rules based on the rules of interpretive information design, explored the logical main line of screen representation content, and made multimedia design followable from the relationship between media, between media and content, and between media and surrounding environment. The basic framework of big data multimedia screen linguistics theory is shown in Figure 1.

Things are universally connected and are organically linked to each other, interdependent and mutually constraining; there are no things that exist in isolation from the surrounding things and conditions. Therefore, in home education statistics, in a particular study not only the thing itself, but also other things that interconnected with it, and find the connection that exists between them through reasonable ways and means. The interdependence between things or phenomena can be broadly divided into two kinds: one is the function relationship, which is a kind of deterministic relationship; that is, when the value of a thing changes, the value of its related things or phenomena will also change accordingly. There is also a correlation, which means that there is a certain relationship between things, which cannot be described by a fixed causal relationship, and at the same time, although the correlation is not definite, it is regular.

Both regression analysis and correlation analysis can be used to describe correlations, and both can measure the relationship between two or more variables to determine the relationship between them. This is what regression analysis and correlation analysis have in common. However, broadly speaking, regression analysis is subordinate to correlation analysis, and strictly speaking, there is a difference between the two. The purpose of correlation analysis is to measure the closeness of the relationship between two random variables. Regression analysis, on the other hand, is more oriented towards changes between variables, describing their relationship through mathematical expressions and thus determining the extent to which a change in one or several variables affects another identified variable [19]. Using multidistance regression analysis, it is possible to determine how closely one independent variable and the dependent variable are related and to detect factors that are less well related, but whether to discard the worst independent variable or whether that independent variable is at all users cannot be simply based on the results of the mathematical treatment and should be considered holistically based on expertise. The current study established the effect of the blended learning experience as the dependent variable and the corresponding independent variables constructed from the blended classroom process experience and closely related to the multimedia screen, and the equation of the multiple regression was expressed as follows:

$$\begin{aligned} Y &= b_0 - b_1 x_1 - b_2 x_2 - \cdots - b_i x_i, \\ Y_i &= X_i \beta - u_i. \end{aligned} \tag{1}$$

Multiple linear regression can use ordinary least squares, maximum likelihood, or distance to estimate the parameters, provided the underlying assumptions met. After the regression function is obtained with the data, statistical tests need to be performed on the sample regression function to determine the reliability of the estimates, and the statistical tests that need to be performed include goodness-of-fit tests, tests of overall linearity of the equations for significance, and tests of significance of the variables:

$$R = \sqrt{\frac{\mathrm{ESS}}{\mathrm{TSS}}}. \tag{2}$$

The prediction of user ratings can be viewed as an act of filling in missing values for a residual user-item rating matrix; that is, given a sparse matrix where the rows are items, the columns are users, and the specific values of the matrix are user-item ratings, the matrix is constructed to fill in the remaining vacant parts to obtain the user-item ratings, assuming a low-rank matrix, the user-item rating prediction is transformed into a minimization problem.

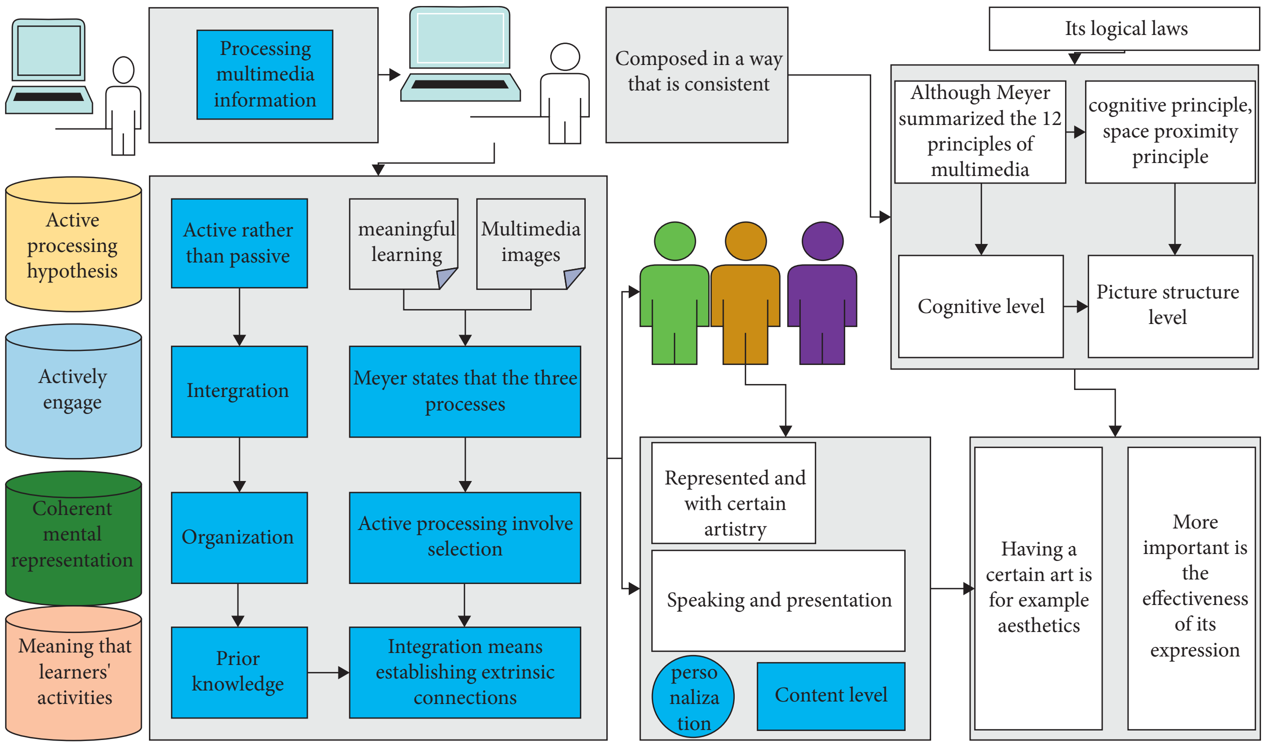

Figure 1: Multimedia art and design big data framework.

$$\arg\max \left\|X_i\right\|^e - \left\|X_i\right\|^2 + \frac{a}{2}\|w(X+Y)\|^e,$$
$$\arg\max \left\|X_i\right\|^2 + \left\|X_i\right\|^2 - \frac{a}{2}\|w(X+Y)\|^e. \tag{3}$$

Large classes are the main form of teaching in China at present, with an average of fifty students per class in primary and secondary schools, and as many as fifty to sixty in colleges and universities, and as few as twenty to thirty, so it is difficult to realize that only one student plays the role of lecturer in each class, but it is possible to work together in small groups to teach a topic. At the same time, conditions should be created for the subordinate information management system to be extended and refined based on this classification system. When students choose a topic, due to the limitations of their knowledge and ability, they need to ask the teacher for advice or learn systematically through the Internet, and so on. Therefore, the hybrid teaching mode needs to be combined with other teaching modes, and collaborative learning and peer-administered teaching can effectively support the hybrid teaching model.

$$\delta = \sum_{i\in U, j\in U}^{R} \sqrt{p_i(r)p_j(r)}. \tag{4}$$

To ensure the accuracy and comprehensiveness of the prediction scores, the prediction results of the blending steps are mixed to obtain the final prediction score matrix.

$$\varphi_i = \frac{1}{1-e^{-\pi i}}. \tag{5}$$

Teaching and learning can be counterproductive. Therefore, teachers need to do a lot of preparatory work when implementing blended learning models. First is that the peer-administered content should be selected considering both the ability level of the giver and the recipient. Second, they should be good at identifying students' strengths and weaknesses. Third is to determine the means of instruction based on the class specifics and the instructional goals of the course. Fourth, the teacher should monitor and guide the entire process, and after assigning tasks to the students, he or she should frequently learn about their progress and guide and supervise them. Fifth is to conduct reasonable teaching evaluation, not only to complete the dissemination of knowledge, but also to focus on the process of comprehensive ability improvement so that this evaluation should serve to check the effectiveness of teaching, but also protect the students' motivation, as shown in Figure 2.

The personalized recommendation method based on potential factors incorporates methods such as matrix decomposition complementation, which not only considers the potential factors of users and items but also considers the respective neighbor information sets of users and items when performing matrix complementation. First, the user rating matrix is constructed, and the user potential factor information and the project potential factor information are modeled and stored in the HBase database, and the user neighbor information set and the project neighbor information set are derived using the similarity calculation formula and stored in HBase; then the original user project rating matrix is matrix-decomposed to obtain the preliminary prediction rating matrix

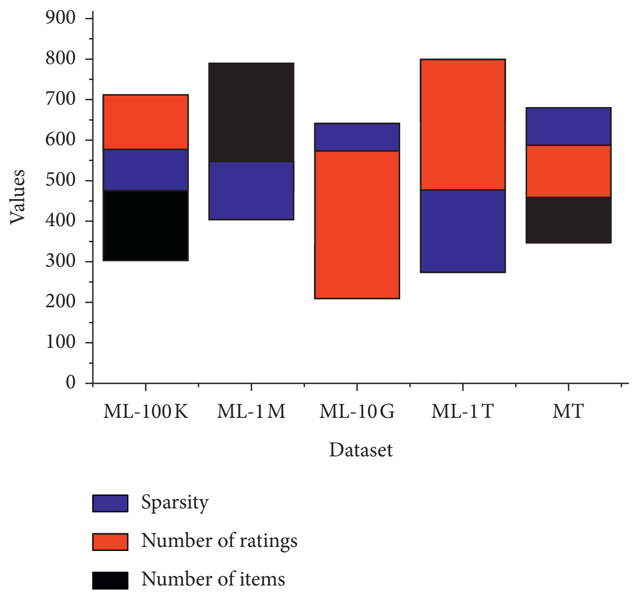

Figure 2: Big data dataset characteristics.

and the true prediction rating error value and stored in the database table. The scoring error values are stored in HBase as database tables.

3.2. Hybrid Multimedia Art and Design Teaching Mode Optimization Design. The principle of systematicity requires that when classifying digital learning images, it is necessary to determine their different subordination and order according to the relevant links of their essential properties so that all digital learning images form a reasonable, orderly, and hierarchical classification system among themselves. The classification of digital learning screens guided by the principle of systematicity helps teachers and researchers to clarify the hierarchical relationship between different screens and their essential properties, which helps to improve the efficiency of classification. The improvement of visual literacy can promote the faster and better development of civilization. Extensibility means setting up shelter categories to ensure that when new things or concepts are added, the established classification system is not disrupted, and it should also create conditions for the lower-level information management system to extend and refine based on this classification system. In other words, the classification of digital learning screens is changed after the design is completed, and small-scale adjustments and changes should be made to the classification rules promptly when there are screens whose essential properties are completely different from the previous classification system or have subordinate relationships.

Practicality requires that the classification criteria for digital learning screens should be such that the actual needs of all relevant units in the system are met as much as possible while meeting the total tasks and requirements of the system. In this study, the classification of digital learning screens developed should first meet the organization and arrangement of all screens based on local disks. The second is to support the subsequent work of this study to achieve accurate identification of digital learning screen emotions, thus enhancing the harmonious interaction between learner emotions and screen emotions in the intelligent learning environment. The encoding of a digital learning picture can help the user to understand the attributes that the picture possesses from the side. For example, a simple encoding can identify the characteristics of the subject to which the screen belongs, the school section to which it belongs, and so on, and facilitate quick retrieval and classification in the computer. In addition, as the database of digital learning screens becomes larger and larger, the need for coding comes to the fore; for example, a standard and stable coding strategy helps to improve the accuracy of classification, the speed of retrieval, and the depth of the database, as shown in Figure 3.

With the rapid development of the Internet, the total amount of digital learning resources has also shown exponential growth. In the research process, it is difficult to manage such many learning images efficiently without a stable and reasonable coding method. With the support of coding, digital learning images with the same properties can be quickly categorized using regular expressions. In addition, when using deep learning to train classification for emotional features of images, the input data can be automatically labeled during the data preprocessing stage to improve training efficiency. Promoting the development of a generation of civilization and progress, the advent of the era of big data has exposed a large amount of information in life, impacting modern people's thinking, attitude, and visual perception.

Sentiment estimation of digitally learned images relies on many digitally learned images as training data, and the amount of training data and labeling accuracy can have an impact on the level of sentiment prediction. In this study, a supervised learning convolutional neural network is used, so image preprocessing such as sentiment labeling of the training data is required before training. According to the previously mentioned emotion-type classification criteria, this study needs to annotate 17,433 digitally learned images according to 14 emotion types: warm, cheerful, lively, funny, exaggerated, humorous, funny, bleak, boring, dull, tedious, unreal, thrilling, and scary, and the annotation intensity is divided into 4 levels, where 0 indicates the lowest intensity and 3 indicates the highest intensity [20]. In this study, 17,433 digital learning images were annotated utilizing paid recruitment of annotators. Except for the necessary training required before the annotation process began, the emotional value of each digital learning image and its intensity calibration depended on the subjective experience of the annotator and was not influenced by the subjective consciousness of the researcher. However, the researcher conducted strict supervision throughout the annotation process to ensure that the entire work was carried out smoothly.

In the modern media course learning, the evaluation link is relatively lacking, and there are also some problems; for example, the evaluation criteria are vague, and the evaluation content is not detailed and clear; the focus on the results of the evaluation, the process of evaluation is lacking. The

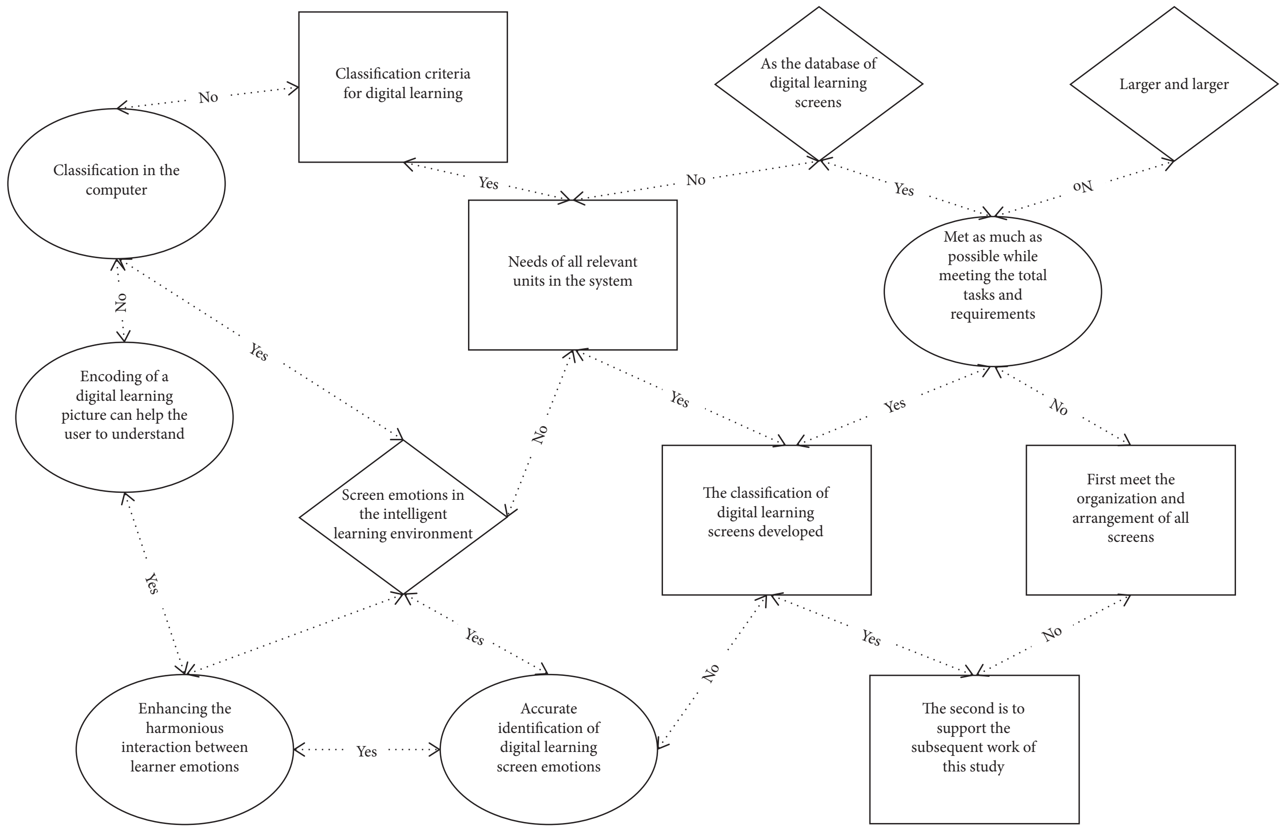

Figure 3: Steps to optimize the hybrid multimedia art and design teaching model.

author also started to think and research that modern media art course learning evaluation tools should be developed, set up learning evaluation dimensions, in the evaluation of modern media art creation and appreciation ability into one, guide students to clarify the fact that modern media art is not only the creation of works media, technical changes, but also learning, creation ideology is subversion and innovation of the concept, and advocate a tiered evaluation. The learning assessment rules for the Truth Modern Media Art learning ability level are shown in Figure 4.

Interesting content in multimedia courseware is designed with the initial intention of attracting students' attention in the hope that they can focus on classroom learning. After investigating the interesting but irrelevant content in multimedia courseware, it was found that 31.21% of the students in this study thought that there was no such irrelevant content that would disturb students' learning [21]. Based on the characteristics of the Internet itself, online network teaching has more information, richer learning resources, and stronger real-time interaction. However, 63.38% of the students believe that there is content in multimedia courseware that disturbs students' learning. Thus, it seems that the content in multimedia courseware needs to be filtered and not interesting for the sake of being interesting.

51.59% of the students said that the matching of text and background colors in multimedia courseware is reasonable and does not cause visual disturbance and redundancy, but 48.41% of the students said that the color matching of multimedia courseware is unreasonable, which also disturbs learning and causes visual redundancy for students. This shows that beautiful multimedia courseware can attract students' attention, but too much pursuit of gorgeous decoration and neglect of the integration with the content of the courseware will also cause visual disturbance and redundancy; or the courseware is too "plain," the content of the courseware is all words, lack of artistry and technicality of the courseware, which will make multimedia teaching. This will make multimedia teaching too dull so that the courseware programming board or the electronic version of the lecture notes will not be able to reflect the advantages of multimedia.

4. Analysis of Results

4.1. Multimedia Art Design Large-Database Design. The total gaze time for the different modules of the multimedia screen represents the sum of the duration of all gaze points within the subject's area of interest, and these data can reflect the extent to which the learner is processing the knowledge. It has become an important issue that must be properly resolved in teaching. In the research of this subject, the author tries to integrate the design concept of unit teaching "disintegrating into a whole" through the modern media art curriculum and strive to focus on teaching goals, optimize teaching content, and make students more comprehensive. A longer gaze time means that the area is more likely to attract the learner's attention or to be more difficult to process. Information that receives more

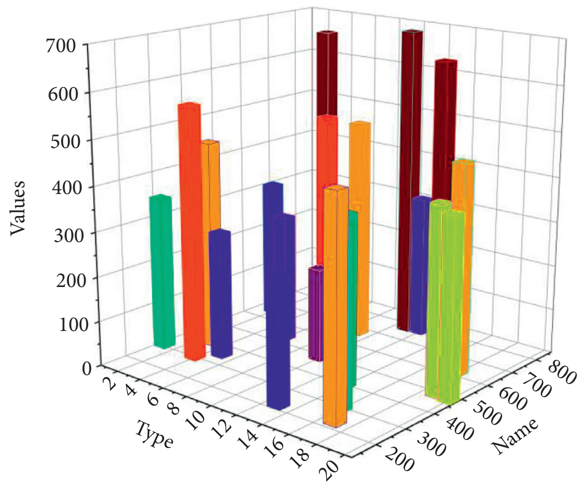

Figure 4: Clarity of instructional information presentation.

attention is more likely to be transmitted for further processing, as shown in Figure 5 below for the total gaze time data for the graphic area. It can be found in the statistics that the average total gaze time in the text area of the whole multimedia screen is significantly longer than the total gaze time of the diagram, which shows that the learners take significantly longer to process the knowledge information described in the text, but it does not mean that the diagram information is not important because the two kinds of information have different characteristics in themselves. Linear, abstract, and comprehensive are the distinctive features of textual language, which is a step-by-step complete expression of the complete content through an idea, requiring a strong logic, and therefore takes more time to read. Diagrams are three-dimensional and visual, and good diagrammatic information can be understood briefly, but it is condensed information and inevitably misses something about what is being expressed. The integrative learning style is more interested in diagrammatic information, and it can combine diagrammatic information more closely and take less time to read when studying.

Subjects with a more sequential style read the text following its logic as well as in step, and the overall time spent is relatively long, as will be reflected in the statistics of the hot-zone data later. As a result, when designing multimedia images, we should ensure that the images and texts are well combined, as this can produce better visual effects and aid readers' memory.

To further explore how students with different learning styles allocate their attention in multimedia screens, this eye-movement experiment was conducted to compare eye-movement hot zones based on four dimensions of learning styles. The digitalization, virtualization, high-speed, technology, specialization, and internationalization of film and television art have been realized. Information technology has also had a profound impact on film and television creation, dissemination and consumption, and film and television aesthetics. The hotspot diagram allows us to visualize the subjects' gaze, revealing differences based on the size, location, and some color areas displayed in the hotspot zones in the diagram. Two hot-zone comparison images with integrated very strong and serial type very weak and integrated very weak and serial type very strong are used, after which they are referred to as integrated and serial type. Integrated students had a slightly smaller gaze range than sequential students and significantly fewer hot zones than sequential subjects. The eye-movement data for the two learning styles were extracted, the average dwell time and the proportion of the two areas in the graphic text, and the average number and proportion of gaze points, as shown in Figure 6.

From Figure 6, it can be found that the total gaze time differs between the two types of students on the same screen, but the ratio of the gaze time on the picture to the time on the text is similar, and a similar pattern can be found by counting the other three dimensions of learning styles. When the narration, background music, and other information are presented to the learner's ears, the acquired information will be processed in the auditory-speech channel. Thus, different learning styles have a similar degree of relative processing of knowledge on the same picture, no picture would differentially affect different learning styles, and therefore multimedia pictures should have regular uniformity rules. Firstly, reference was made to existing questionnaires related to blended learning and multimedia screens, and Professor You Sewing's literature related to the language of multimedia screens and blended learning was also consulted and studied and then analyzed with due characteristics, and 13 variables were established from three aspects. After that, it was sent to the tutor and the students of educational technology to collect feedback for modification.

4.2. Results of the Optimization of the Hybrid Multimedia Art and Design Teaching Model. The distribution of positive emotions in both the university and social education levels showed a significant downward trend compared to the other segments, while emotions such as dull and dreary showed a significant increase, and the level of the distribution of negative emotions in these two segments was already higher than the level of positive emotions. There is a certain degree of art such as aesthetics, but more importantly, the effectiveness of its expression and its logical laws can be explored from the content level, the cognitive level, and the picture-structure level. Among the other emotion types, the distribution of emotions such as tedious, thrilling, and scary does not differ significantly from the distribution of the above three academic periods, except for unreal, which has increased. From the distribution of emotions, the design of teaching resources at the university and social education levels focuses more on the transmission of knowledge content, and the images are boring and have a single layout, which makes it difficult to convey positive emotions to learners in terms of visual characteristics. Figure 7 provides a visual representation of the distribution of emotions in each digital learning screen by school level.

The warm emotion type of digital learning screen is mainly present in teaching methods such as playing sound, animation, multimedia PPT, image, drawing, classroom, etc.

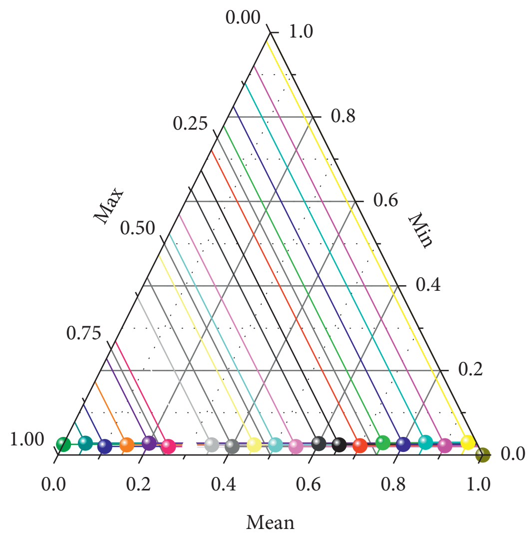

Figure 5: Description statistics of attention time.

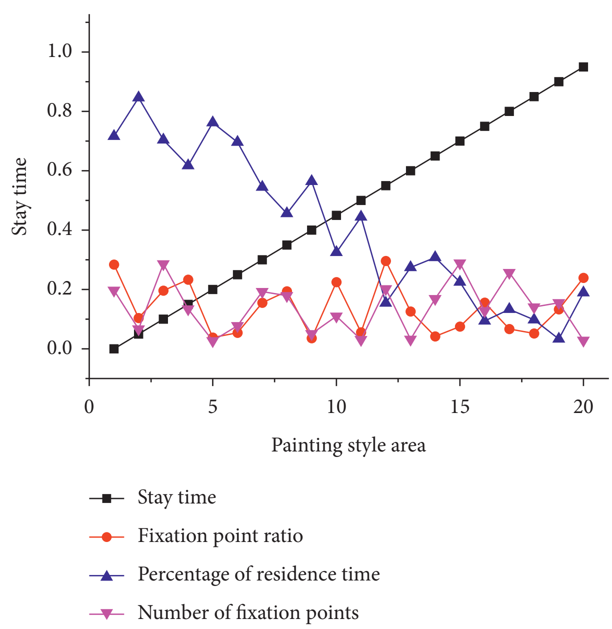

Figure 6: Description of learning style interest area differences.

The level of warm emotion distribution of other types of resources is below 20%. The distribution of warm emotions in videos and web pages is 6.25% and 1.68%, and the lowest distribution of warm emotions in human-computer interaction is only 0.15%. The cheerful emotion type is mainly found in the two teaching methods of animation and playing sound, and the distribution of other types of resources is also lower than 20%, especially in the teacher and teaching content, video, web page, human-computer interaction, and classroom, the distribution level of cheerful emotion is less than 5%. The lively emotion type is mainly found in the text-based teaching approach, probably because text-based resources enhance the visual characteristics of the resource due to a well-designed typographic layout and color scheme, which enhances the level of positive, lively emotion on the screen. The distribution of lively emotion in resources such as teacher's single lecture, teacher's teaching content, human-computer interaction, experimental training, and web page is low, all below 5%. The funny emotion type is mainly distributed in the animation teaching method, and the animation-type resources are usually well designed with color and layout, which can convey good visual emotion characteristics. In contrast, the level of distribution of funny emotions is below 10% in all other types of images. The three emotions of exaggerated, humorous, and funny are not distributed high in all types of images, with the distribution of both humorous and funny emotions below 1%, and most of the images have difficulty in reflecting the metaphorical characteristics of these two emotions.

Multimedia-assisted teaching in colleges and universities should start by changing the traditional teaching concept, establishing the teaching concept of students as the main body of the classroom, and carrying out classroom teaching from the perspective of facilitating students' learning and teachers' teaching while suggesting that teachers can apply a variety of teaching aids for diversified knowledge exchange. At the same time in the actual multimedia-assisted teaching teachers in addition to updating the concept of education and teaching, it should be clear that multimedia technology is only an auxiliary technical tool for teaching, rather than teaching. Multimedia-assisted teaching in colleges and universities should start by changing the traditional teaching concept, establishing the teaching concept of students as the main body of the classroom, and carrying out classroom teaching from the perspective of facilitating students' learning and teachers' teaching while suggesting that teachers can apply a variety of teaching aids for diversified knowledge exchange. Meanwhile, in the actual multimedia-assisted teaching, teachers should make it clear that multimedia technology is only an auxiliary technical tool for teaching, not teaching, in addition to updating the concept of education and teaching, as shown in Figure 8.

Modern information technology is an important manifestation of science and technology, but today's society is a society in which economic capital occupies a major position. The main reason modern information technology has been promoted to such a high position and why it has been continuously improved and developed also lies in its value and the needs of the market, as well as the pursuit of profit, or the value orientation of contemporary society and film and art, which puts forward the information technology to a higher level of pursuit. When the value of a thing changes, the value of the thing or phenomenon related to it will also change accordingly. There is also a correlation, which refers to the fact that there is a certain relationship between things, which cannot be described by a fixed causal relationship. At the same time, although the correlation is not certain, it is regular. Thus, the face of technology or the manifestation of modern information technology is essentially a technology of the economy, even profit-oriented technology. The technology of economy or capital with science and technology, as the main means of benefiting the most, pushes technology to the center of the art of film and television. The

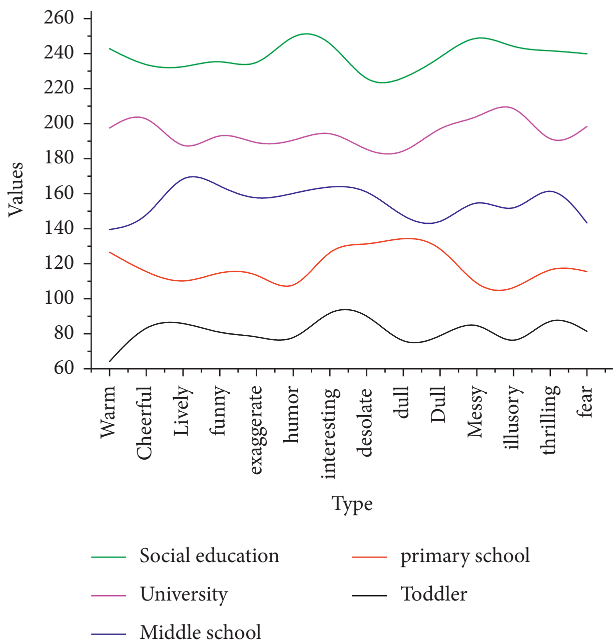

Figure 7: Distribution among school segments.

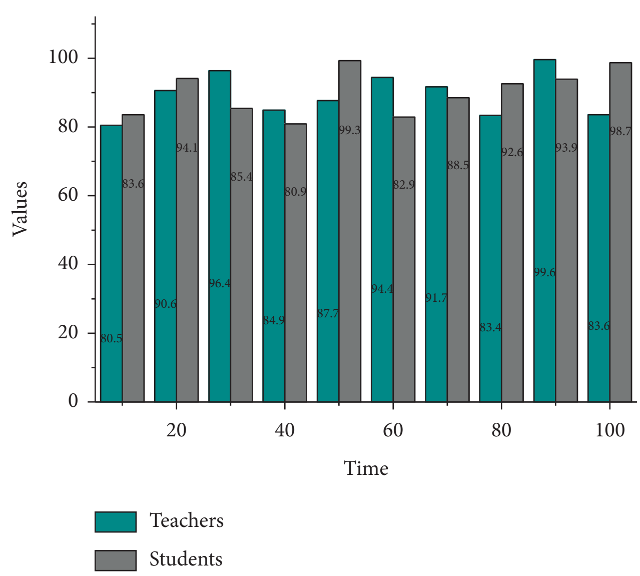

Figure 8: Evaluation results.

character of modern information technology, then, depends not only on the profitability of film and television art but also on the rational needs of modern film and television art that permeate the ultimate modern information technology, especially the scientific rationality of the needs of film and television art under mass aesthetics.

5. Conclusion

Art museum education in the context of the big data era faces more challenges and opportunities and opens a new chapter of development for art museum education. The booming development of big data has changed people's way of accessing information from active to passive, and in this transformation process, recommendation system has a crucial role. Recommendation algorithm is the key technology of recommendation system; the traditional recommendation algorithm still has the problems of cold start, high data sparsity, and so on. The prediction accuracy of the recommendation algorithm is an important criterion to measure the goodness of a recommendation system. Modern information technology has brought a great impact on the development of modern society because of its wide, fast, and technological communication, and for the development of film and television art, information technology not only makes its creative field and subject matter selection more extensive, but also it does limit the content of creation to reality. Modern information technology has broken the traditional time and space pattern, expanding the space and time of film and television production, making the impossible possible, and creating more infinite space and time possibilities through computerized postproduction of special effects. Modern information technology will also make the dissemination of film and television art more diversified and multichannel and obtain more infinite possibilities of film and television art, and the influence of film and television art will also be accompanied by the development of modern information technology and break through the traditional means of creation and expression so that the impossible becomes possible and dreams become reality.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author does not have any possible conflicts of interest regarding the publication of this work.

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Research Article

Evaluation of Government Ecological Environment Governance Effect from the Public's Perspective Based on the Entropy Method: Take the Kubuqi Desert in Inner Mongolia as an Example

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The Kubuqi Desert is the seventh-largest desert in China. Under the leadership of the central, autonomous region and local governments, the ecological situation has undergone historic changes. In this paper, we select Hangjin Banner and Dalate Banner, which have the most widely distributed deserts and use 347 households as the research perspective to construct the evaluation index system of the government's ecological environment governance effect. The entropy method is used to evaluate the governance effect, and the ordinary least squares and quantile regression are used to compare the evaluation differences of different publics. The research found the following. (1) The public believes that the government's ecological governance measures have achieved good results in the third-level index analysis. The ecological environment in the desert area has been significantly improved; that is, the survival rate of trees has increased, the area of vegetation coverage and vegetation types have increased, and the frequency of sandstorms has decreased. However, the intensity of sandstorms and the flow of water sources did not change significantly. The various types of public income have increased significantly compared to before the governance. The public takes the ecological priority as the concept and actively participates in the government's governance implementation, which means that the ecological awareness and behavior are higher. (2) Among the second-level index, the weights and scores in descending order are public economic characteristics: 45.53% and 0.4840, public ecological behavior: 25.62% and 0.1682, public ecological effect perception: 18.35% and 0.1240, and public ecological awareness: 10.51% and 0.0291. The comprehensive evaluation result is 0.8054, which is in the first grade, and the effect is excellent. (3) The public comprehensive evaluation results of the two regions are similar. Hangjin Banner is 0.8209 and Dalate Banner is 0.8557, both in the first grade. The effect is excellent. (4) In the OLS regression results, gender has a significant positive impact on evaluating the government's ecological environment governance effect. Age, ethnicity, and occupation have a significant negative impact. As the quintile increases, the influence of gender, age, and ethnicity first increases and then decreases. The maximum regression coefficient of gender at the 50% quantile is 0.714, which has a significant positive effect. Age has a significant negative impact at each quantile. The regression coefficient of ethnicity at the 50% quantile is the highest -0.357, which has a significant negative impact. Occupation only has a significant negative impact at the low quintile.

1. Introduction

In today's increasingly severe ecological environment problems, countries worldwide are actively exploring ways to realize the rational development and utilization of environmental resources. Over the years, the Inner Mongolia Autonomous Region, as one of the provinces with more severe ecological and environmental problems in China, has made some gratifying achievements and valuable experience in environmental governance. In particular, the ecological environment management of the Kubuqi Desert has become a representative case in environmental environment management, sand prevention, and control in the Inner Mongolia Autonomous Region, China, and even the world. In a broad sense, environmental governance refers to the management of human social and economic activities through the extensive use of financial, technological, legal, and administrative means within the scope of environmentally permitted capacity, following the scientific guidance of environmental theory. In a narrow sense, to achieve the expected environmental goals, managers should prevent and control the pollution impacts produced in social and economic development to achieve the unity of economical, social, and ecological benefits [1]. The United Nations Development Program (UNDP) and the United Nations Environment Program (UNEP) pointed out how to make environmental decisions and who makes decisions. This process is called environmental governance [2]. That is to say, environmental governance is the exercise of power over natural resources and the environment, including the decision-making process of laws and public institutions such as government agencies and village committees to make power specific. As the primary embodiment of national or local existence, government agencies occupy the core position and leading role in the governance of many fields [3], including the area of ecological environment governance.

Relying on the natural resources and climatic characteristics of the Kubuqi area, the government formulated a "focus on forest and animal husbandry, diversified management" from the end of the 1970s. Comprehensive management of the Kubuqi Desert began in the 1980s. The construction of "planting three and five small" (planting trees, planting grass, planting Caragana korshinskii, small watershed, small water conservancy, small fenced pasture, small economy, small farming, and animal husbandry machinery). Simultaneously, the desolate sand, empty beach, slope, desolate ditch, and desolate mountain are allocated to households to encourage planting trees and grass, managed by farmers and herders. In the 1990s, vegetation construction was regarded as the most significant infrastructure construction. During this period, the Kubuqi region implemented various ecological and economical projects following "resource development and environmental protection" principles, adapted to local conditions, classified guidance, regional implementation, and gradient promotion [4]. By 2000, the policy of "grazing prohibition, rest grazing, rotation grazing, stall-feeding and half-feeding, and transfer of farmers and herdsmen" will be implemented. The Kubuqi Desert is designated as a prohibited development zone. They are carrying out ecological immigration, guiding enterprises to join environmental governance, and building ecological industries of desert tourism, desert medicine, and circular desert economy [4, 5]. After 2012, the Kubuqi region has practiced Xi Jinping's ecological civilization thought, incorporated desertification into the overall national economic and social development plan, and implemented a local administrative leadership responsibility system. And encourage the whole society to participate in ecological construction and increase the application of science and technology in environmental governance. The ecological situation has achieved a historic change. The international community has highly recognized Kubuqi's ecological governance achievements and experience. In 2014, the United Nations Environment Program established the Kubuqi Desert Ecological Management Zone as a "Global Desert Ecological Economic Demonstration Zone." In 2015, the United Nations Climate Conference in Paris shared Kubuqi's desertification control as a "Chinese sample." In 2017, the United Nations released the world's first desert ecological wealth report and the world's first case of China's ecological civilization construction recognized by the United Nations and the international community [5].

Scholars are concerned about the macrolevel natural environment of the Kubuqi Desert [6], governance process, governance policies and measures, governance effectiveness (Qi Hailin, 2017) [5, 7], and empirical enlightenment [8, 9]. The microlevel government-led ecological environment governance [10, 11], the effect of ecological migration [12], land use under governance policies [13, 14], and other aspects are less content. In particular, the research on governance effects based on the public's perspective is relatively lacking. The methods, indicators, and corresponding evaluation results are different based on evaluating the ecological environment governance effects of different subjects [15]. At present, the evaluation of ecological governance effects from the public's perspective includes analytic hierarchy process (AHP) decision analysis method [15], analytic hierarchy process (AHP)-fuzzy comprehensive evaluation (FCE) method [16], entropy method [17, 18], etc. Different methods have their advantages and disadvantages. In this paper, the entropy method is used to evaluate the governance effect. At the same time, the ordinary least squares regression and quantile regression are used to compare the evaluation differences of different publics. In this way, we provide help for follow-up governance.

2. Materials and Research Methods

2.1. Overview of the Research Area

2.1.1. Geographical Distribution Overview. The Kubuqi Desert is located on the northern edge of the Ordos Platform, on the southern bank of the Yellow River, facing the Mu Us Sandy Land in the south. It is 360 kilometers long from east to west and 40 kilometers wide from north to south. They are distributed in Hangjin Banner, Dalate Banner, Zhungeer Banner, Yijinhuoluo Banner, and Dongsheng District of Ordos City. However, they are mainly distributed in Hangjin Banner and Dalate Banner. Therefore, choose Hangjin Banner and Dalate Banner for analysis. In the mid-1990s (Table 1), the total area of the Kubuqi Desert was 18,500 square kilometers. The results of the 5th China National Desertification and Sandification Inventory Monitoring show that the total area of the Kubuqi Desert is 14,100 square kilometers. Among them, the desert area in Hangjin Banner is 10,600 square kilometers, accounting for 75.37% of the total desert area. Dalate Banner covers an area of 2,386 square kilometers, accounting for 16.92%. The two places account for 92.29% of the whole desert area.

Table 1: Kubuqi Desert in the mid-1990s and the 5th China National Desertification and Sandification Inventory Monitoring and distribution data comparison (unit km^2).

Statistical unit	Desert area	Mobile dune/ land	Accounted for the total desert area (%)	Semifixed dune/land	Accounted for the total desert area (%)	Fixed dune/ land	Accounted for the total desert area (%)
Mid-1990s	18517.85	9074.26	49.00	1675.28	9.05	7768.31	41.95
The 5th China national desertification and sandification inventory monitoring	14111.52	5331.33	37.78	2532.59	17.95	5125.89	36.32
Hangjin Banner	10635.85	4669.67	33.09	2342.84	16.6	2975.89	21.1
Dalate Banner	2386.93	638.65	4.52	148.41	1.05	1331.53	9.43

Note. The data comes from Yang Wenbin, The natural environment and comprehensive management of Kubuqi Desert [M], Inner Mongolia University Press, 2005 and data obtained from the survey.

2.1.2. Socio-Economic Overview. **Agriculture and animal husbandry production:** the total output value of farming, forestry, animal husbandry, and fishery in Hangjin Banner increased from 28.05 million yuan in 1978 to 4.020 billion yuan in 2020, an increase of 99.3%; the total number of livestock and total grain output increased by 55.5% and 94.1%, respectively, at the end of the year (Figure 1). The total output value of farming, forestry, animal husbandry, and fishery in Dalate Banner has increased from 36,47million yuan in 1978 to 753,603.97 million yuan in 2020, an increase of 99.52%; the total number of livestock and total grain output increased by 75.6% and 91.1%, respectively, at the end of the year (Figure 2). **Regional economy:** Hangjin Banner's GDP increased from 26.31 million yuan in 1978 to 12883.26 million yuan in 2020, an increase of 99.8%; public finance budget revenue, public finance budget expenditure, and per capita net income of farmers and herdsmen increased by 99.6%, 99.8%, and 99.2%, respectively (Figure 3). Dalate Banner's GDP increased from 53.63 million yuan in 1978 to 31969.72million yuan in 2020, an increase of 99.8%; public finance budget revenue, public finance budget expenditure, and per capita net income of farmers and herdsmen increased by 99.8%, 99.7%, and 98.9%, respectively (Figure 4).

2.2. Data Sources

2.2.1. Questionnaire Survey. From October 2019 to August 2021, the author selected 10 Sumu and towns (Table 2) in Hangjin Banner and Dalate Banner to conduct a random household questionnaire survey. A total of 405 questionnaires were issued, with 347 valid questionnaires, and the efficiency is 85.68%.

2.2.2. Basic Information of the Sample. There are more males in the sample (69.16%), and 60.81% of the interviewees are over 41 years old, and they have participated in the management of the Kubuqi Desert and the construction of desert-crossing highways. Among them, the Han nationality accounted for 62.54% and the Mongolian nationality accounted for 37.46%. The education level of technical secondary school and above accounted for 50.72%, and the overall educational level was relatively high. Half-agricultural and half-pastoral households accounted for the largest proportion of households, accounting for 23.63%. "3–4 persons" accounted for the largest proportion of the family population, at 66.29%. In terms of total household income and per capita net income, the proportion of each income segment varies greatly (Table 3).

2.3. Research Methods

2.3.1. Entropy Method. The entropy method can transform Kubuqi's public's subjective, long-term, and qualitative continuity judgments of the governance process into quantitative data [18]. The main steps of the entropy method to determine the weight coefficient:

(1) Construct the original data matrix:

$$A = \left(x_{ij}\right), i = 1, 2, \ldots, 347, j = 1, 2, \ldots, 22, \quad (1)$$

where i represents the number of citizens participating in the evaluation and j represents the number of evaluation indexes.

(2) Data standardization: the standardization basis for positive indexes and moderate indexes:

$$x = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}}. \quad (2)$$

The proportion of income from crops and the proportion of income from farming, which are moderate indexes, are standardized based on the average value within the group:

$$x = \frac{|x_{ij} - avgx_{ij}|}{|avgx_{ij} - \min x_{ij}|}. \quad (3)$$

(3) Unified quantification of indicators, calculating the weight of the jth index,

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}. \quad (4)$$

(4) Calculate the entropy value of the jth index:

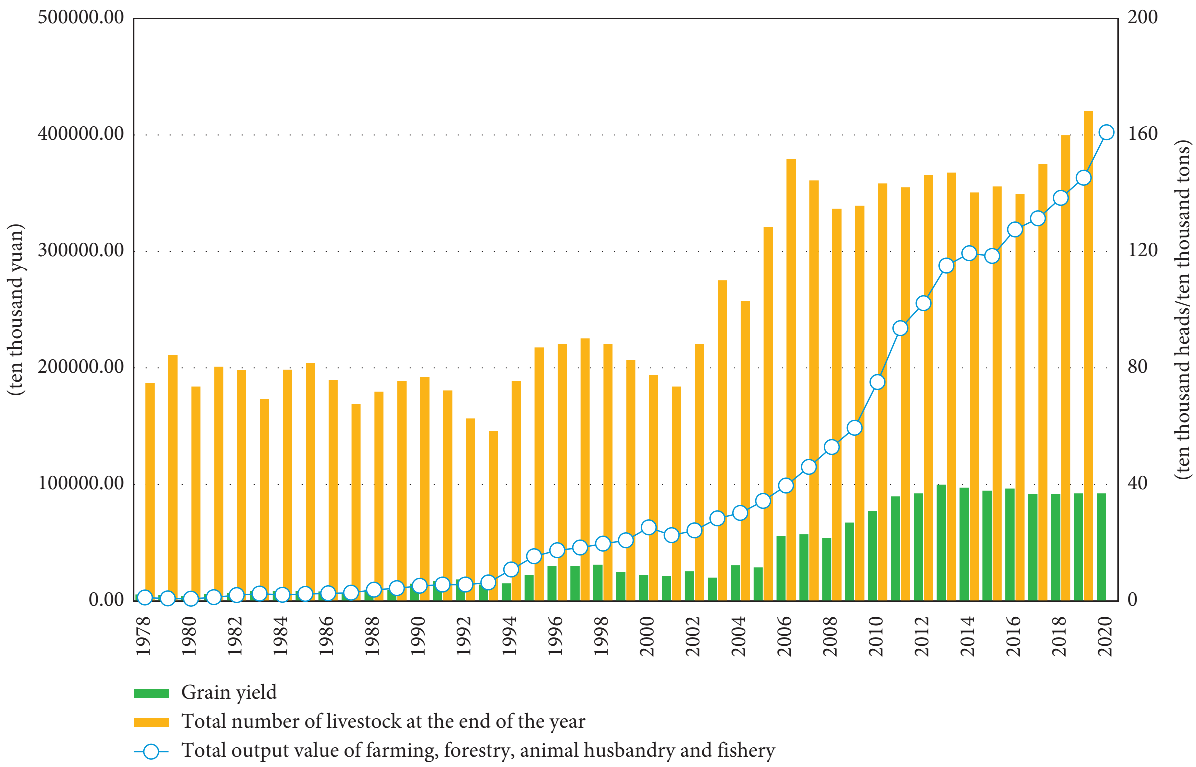

Figure 1: Main agricultural production statistics index of Hangjin Banner.

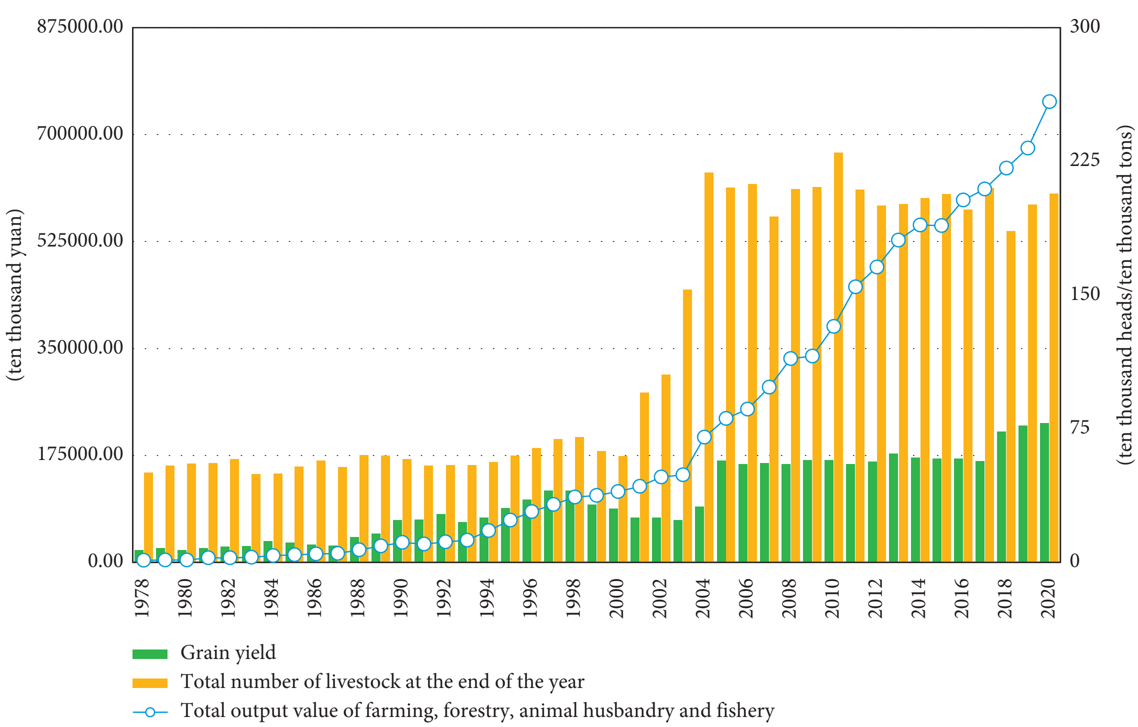

Figure 2: Main agricultural production statistics index of Dalate Banner.

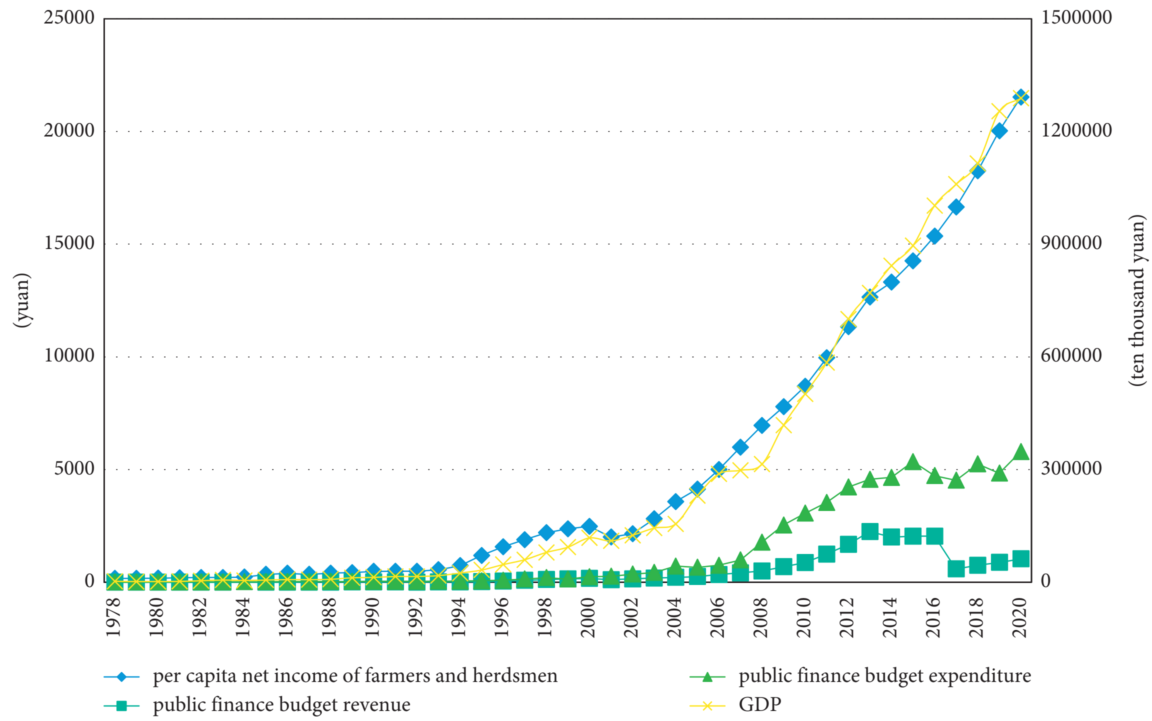

FIGURE 3: Main regional economic statistical index of Hangjin Banner.

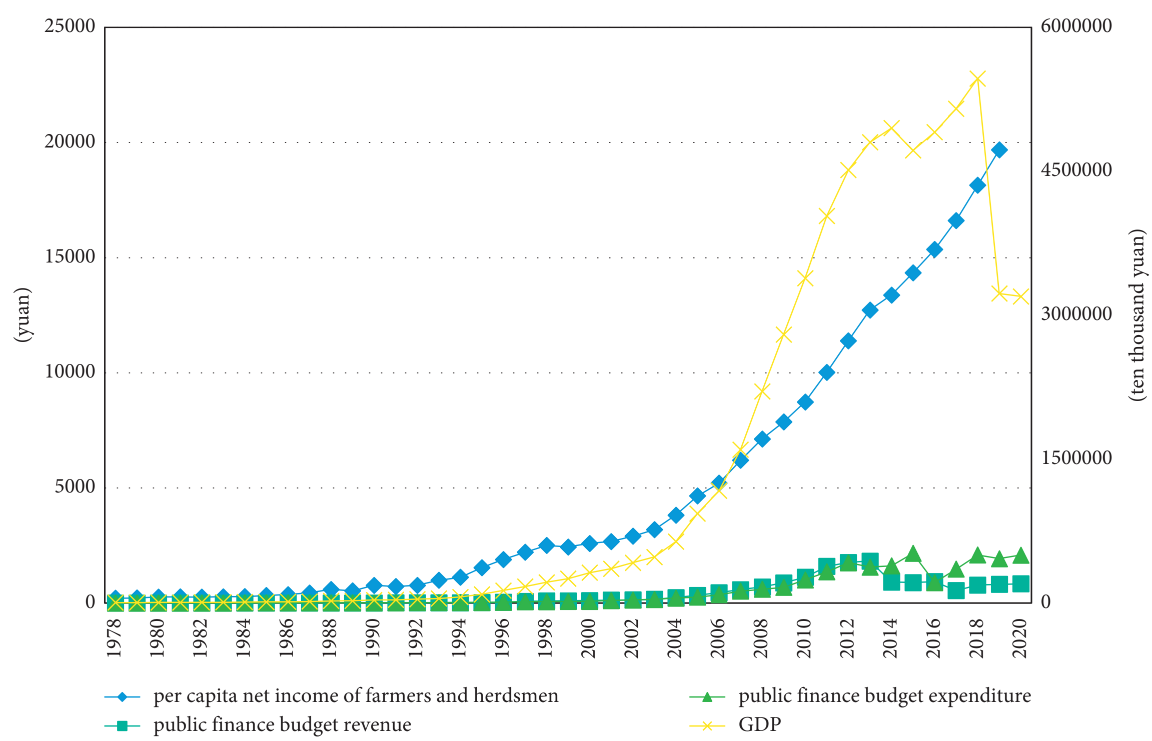

FIGURE 4: Main regional economic statistical index of Dalate Banner. *Note.* The data are derived from the “Inner Mongolia Statistical Yearbook,” “Ordos Statistical Yearbook,” and the statistics of the National Economic and Social Development Bulletin of Hangjin Banner and Dalate Banner in 2020.

Table 2: Distribution of the sample area.

Banner county name	Sumu (town)
Hangjin Banner	Jiri Galangtu Town, Duguitala Town, Yihe Wusumu, and Xini Town
Dalate Banner	Engebei Town, Zhandanzhao Sumu, Shulinzhao Sumu, Wangaizhao Town, Bainijing Town, and Zhonghe West Town

Table 3: Descriptive statistics of sample data.

Population characteristics	Attributes	Number of people	Proportion (%)	Population characteristics	Attributes	Number of people	Proportion (%)
Gender				Nationality			
	Male	240	69.16		Han nationality	217	62.54
	Female	107	30.84		Mongolian	130	37.46
Age				Family household			
20 years old and below		1	0.29		Pure animal husbandry	54	15.56
21–30 years old		62	17.87		Pure farmer	61	17.58
31–40 years old		73	21.04		Half-agricultural and half-pastoral	82	23.63
41–50 years old		90	25.94		Other	150	43.23
50–61 years old		69	19.88	Occupational situation			
Over 60 years old		52	14.99		Farming	124	35.73
Education					Nonagricultural and animal husbandry self-employed	53	15.27
Elementary school and below		20	5.76		Students	13	3.75
Primary school		48	13.83		Inability to work	13	3.75
Junior high school		68	19.60		Public officials	144	41.50
High school		35	10.09	Total household income			
Technical secondary school		18	5.19		Less than 5,000	156	44.96
Junior college		32	9.22		5,000–20,000	18	5.09
Undergraduate		108	31.12		20,000–50,000	19	5.38
Postgraduate and above		18	5.19		50,000–100,000	26	7.49
Family population size					More than 100,000	129	37.08
1 person		12	3.46				
2 person		77	22.19	Per capita income			
3 person		129	37.18		Less than 5,000	79	22.77
4 person		101	29.11		5,000–20,000	156	44.96
5 person		9	2.59		20,000–30,000	39	11.24
6 person and above		19	5.48		More than 30,000	73	21.04

$$e_j = -k \sum_{i=1}^{n} P_{ij} \ln P_{ij}, \text{where k is equal to} \frac{1}{lni}, k > 0. \quad (5)$$

(5) Calculate the difference coefficient of the jth index:

$$g_j = 1 - e_j. \quad (6)$$

(6) Calculate the weight of the jth index:

$$w_{j=}\frac{g_j}{\sum_{j-1}^{m} g_j}, \quad (7)$$

w_j is the final weight of each quantified third-level evaluation index. According to the principle of additivity of the index at the same level [17], the second-level index weight is the sum of the corresponding third-level index weights and can be obtained the first-level index weight in the same way.

(7) Calculate the public's evaluation of the effect of ecological governance:

$$E_j = \sum w_j x_j. \quad (8)$$

According to the principle of the additivity of the statistical index scores of the entropy method [17], the second-level index score is the weighted summation of the corresponding third-level index scores and can be obtained the first-level index score in the same way.

2.3.2. Quantile Regression. Quantile regression has strong robustness for outliers, normality of dependent variables, or heteroscedasticity problems [18]. The model is as follows:

$$y_q(x_i) = x_i\beta_q, \quad (9)$$

where y is the evaluation result of the public's ecological governance effect, x_i is the factor that affects the public evaluation result, and β_q represents the q-quantile regression coefficient, and its value is

$$\beta_q = \min \sum_{i:\ y_i \geq \beta_q x_i}^{n} q\left|y_i - \beta_q x_i\right| + \sum_{i:\ y_i < \beta_q x_i}^{n} (1-q) + \left|y_i - \beta_q x_i\right|. \quad (10)$$

3. Results and Analysis

3.1. Construction of the Evaluation Index System. Based on the principles of systematicity, pertinency, stability, discrepancy, and measurability [17, 18], we refer to relevant domestic and foreign literature [18]:

(1) The public's perception of the ecological effects of governance
(2) Influence the effects of ecological governance
(3) The level of public economic development is affected by or related to ecological governance
(4) The public's willingness to participate in ecological governance and environmental awareness, respectively, correspond to the four second-level indicator standards

That is the public's perception of ecological effects, ecological behavior, their economic level, and ecological awareness. Under each second-level index, several third-level indexes are set as the scheme layer. See Table 4, for specific indicators and connotations.

3.2. Overall Evaluation Results. To directly reflect the effect of ecological environment governance, scholars divide the evaluation index of government ecological environment governance effect into five grades [17, 18], see Table 5.

3.2.1. Third-Level Index Result. In the third-level index (Table 6), the index factor value is the average value of the same sample data as the evaluation value. C1, C2, C4, and C5 are positive indicators with evaluation grades ranging from 1–5. Their factor values are all greater than 4, indicating that the public perceives that the ecological environment of the Kubuqi area under the government's leadership has significantly improved, that is, the survival of trees has increased, the area covered by vegetation, and the types of vegetation have increased. At the same time, the frequency of sandstorms has decreased a lot. Still, the intensity of C3 sandstorms and the flow of C6 water sources have not changed significantly. 96.25% of the people in the questionnaire believe that the environment in the sandy area has been significantly improved. As of 2016, the governance area of the Kubuqi Desert reached 6,460 square kilometers and a green area of more than 3,200 square kilometers. The forest and vegetation coverage has increased from 0.8% and 16.2% in 2002 to 15.7% and 53% [5]. Among them, the artificial afforestation area of Hangjin Banner and Dalate Banner in 2019 was 10.41 thousand hectares and 5.17 thousand hectares, an increase of 76.4% and 19.7% over 2018. Dust weather decreased from more than 50 times in 1988 to one time in 2016, rainfall increased from less than 100 mm to 456 mm, and biodiversity increased to more than 530 types [5].

C8, C20, and C22 indicate that the public believes that the government's ecological governance measures have achieved specific results, with high satisfaction and confidence in sustainable governance. An average of 93.85% of the respondents in the questionnaire also agreed that the Kubuqi Desert governance is a scientific and successful governance case, and it will have better development in the future. C13 is the weight and score of the channel type for obtaining ecological policy information are the second, occupying the central position, indicating that getting governance policy information is one of the public's evaluation criteria for the effectiveness of government governance. If the public information is not comprehensive enough, not transparent enough, and asymmetrical, it will make the overall government governance become water without a source and a tree without roots. C14, C15, C16, and C17 are the rate of change and satisfaction of various incomes before and after ecological governance. The weights and scores are all the top 5, indicating that multiple revenues such as agriculture, animal husbandry, labor, and government subsidies have increased significantly compared to before the governance. The government's ecological migration policy provides a monthly social security subsidy of 350 yuan per person in addition to cash and housing subsidies for herders in sandy areas. Guide enterprises to transfer more than 1.5 million acres of sandy land to farmers and herdsmen in sandy areas, and farmers and herdsmen also earn income through land entering agriculture. Since 2017, 12 villages and towns around Kubuqi have more than 5,500 people through the traditional Chinese medicinal planting model represented by licorice have been benefited. C9 and C10 indicate that taking others as the reference object, the respondents believe their sand area activities are significantly less than others. This result may be due to the external expected pressure brought by the questionnaire to the respondent. There may be a self-perception bias, which will eventually lead to biased results. C19, C21, C11, C12, and C18 indicate that the public prioritizes ecology, which means they have higher ecological awareness and behavior.

3.2.2. Second-Level Index Results. In the second-level index results (Table 6), the weights and scores in the descending order are B3 public economic characteristics 45.53% and 0.4840, B2 public ecological behavior 25.62% and 0.1682, B1 ecological effect perception 18.35% and 0.1240, and B4 public ecological awareness 10.51% and 0.0291. It shows that the government should prioritize economic construction and ecological behavior in the process of governance. 93.65% of the people said that the ecological environment governance has significantly improved the region and their economy. Also, 92.5% of the people felt that the governance had brought positive social benefits. In recent years, the economy of Kubuqi has continued to develop, creating a desert economy with the integration of the tertiary industry and complementing each other, which has driven 102,000 people out of poverty. Their income has increased from less

Table 4: Evaluation index system of government ecological environment governance effect.

First-level index	Second-level index	Third-level index	Index value description
Evaluation index system of government ecological environment governance effect	Public ecological effect perception B1	C1 tree survival rate	5 = *a* lot of increase, 4 = *a* minor increase, 3 = no change, 2 = *a* minor decrease, and 1 = *a* lot decrease
		C2 sandstorm frequency	5 = decrease a lot, 4 = decrease some, 3 = no change, 2 = increase some, and 1 = increase a lot
		C3 sandstorm intensity	5 = weaken a lot, 4 = weaken a little, 3 = no change, 2 = enhance a little, and 1 = enhance a lot
		C4 vegetation coverage area	5 = *a* lot of increase, 4 = *a* minor increase, 3 = no change, 2 = *a* minor decrease, and 1 = reduce a lot
		C5 vegetation type	Same as above
		C6 water flow changes	Same as above
		C7 oasis blocks the effect of wind and sand	Same as above
		C8 whether government governance meets expectations	4 = good governance effect has been achieved, 3 = there is ecological governance effect, but the governance effect is not up to expectations, 2 = there is no governance effect, and 1 = unclear
	Public ecological behavior B2	C9 types of economic activities of others in the sand area	5 = no activity, 4 = 1–2 activities, 3 = 3–4 activities, 2 = 5–6 activities, 1 = 7 activities, and above
		C10 types of economic activities in the respondent's sandy area	
		C11 whether to stop other people from destroying the ecological environment of the sandy area	3 = stop, 2 = report to relevant government organizations or departments, and 1 = don't care
		C12 frequency of participating in collective desertification voluntary labor	3 = participate often, 2 = participate occasionally, and 1 = never
		C13 types of channels for obtaining ecological policy information	1–5 represent the number of ways to obtain information
	Public economic characteristics B3	C14 the ratio of crop income to total income	The ratio of grain and cash crops to total income (%), comparison before and after treatment
		C15 the ratio of aquaculture income to total income	The income ratio from raising cattle and sheep to total income (%), the same as above
		C16 the ratio of other income to total income	Other income includes labor, self-employment, wages, financial subsidies, and land lease, the same as above
		C17 satisfaction with current household income	5 = very satisfied; 4 = satisfied; 3 = fair; 2 = not very satisfied; 1 = not satisfied
	Public ecological awarenessB4	C18 whether to consider sustainable production and lifestyle	2 = yes and 1 = no
		C19 the importance of economy and environment	3 = it is necessary to protect desert vegetation, 2 = the two are equally important, and 1 = it is important to develop the economy
		C20 the future ecological environment of the Kubuqi area	3 = the ecological environment will be restored, 2 = it is hard to say and it depends on the specific measures of governance, and 1 = the oasis disappears
		C21 whether to support the state or related organizations to implement governance policies and projects in the Kubuqi area	2 = yes and 1 = no
		C22 satisfaction with the various governance policies implemented in the Kubuqi area	3 = satisfied; 2 = dissatisfied; 1 = unclear

Table 5: The grading standard of the government's ecological environment governance effect evaluation index.

Grade	1	2	3	4	5
Evaluation index	0.8–1.0	0.6–0.8	0.4–0.6	0.2–0.4	<0.2
Meaning	Excellent	Good	Ordinary	Poor	Very bad

Table 6: Empirical results of evaluation of government ecological environment governance effects.

Third-level index						Second-level index			First-level index
Index	Entropy	Difference coefficient	Index factor value	Index weight	Score	Index	Index weight	Score	Overview
C1	0.9962	0.0038	4.4300	0.0172	0.0762	B1	0.1835	0.1240	A 0.8054
C2	0.9958	0.0042	4.4100	0.0192	0.0847				
C3	0.9951	0.0049	2.7700	0.0224	0.0620				
C4	0.9967	0.0033	4.4800	0.0152	0.0681				
C5	0.9967	0.0033	4.3800	0.0149	0.0653				
C6	0.9897	0.0103	3.6500	0.0469	0.1712				
C7	0.9968	0.0032	2.8300	0.0147	0.0416				
C8	0.9927	0.0073	3.2400	0.0330	0.1069	B2	0.2562	0.1682	
C9	0.9957	0.0043	3.7800	0.0194	0.0733				
C10	0.9969	0.0031	4.0300	0.0139	0.0560				
C11	0.9937	0.0063	2.5300	0.0286	0.0724				
C12	0.9896	0.0104	2.2200	0.0472	0.1048				
C13	0.9676	0.0324	2.3800	0.1471	0.3501	B3	0.4553	0.4840	
C14	0.9638	0.0362	1.9000	0.1643	0.3122				
C15	0.9690	0.0310	1.6600	0.1405	0.2332				
C16	0.9752	0.0248	3.4500	0.1127	0.3888				
C17	0.9917	0.0083	3.4100	0.0378	0.1289	B4	0.1051	0.0291	
C18	0.9968	0.0032	1.9700	0.0147	0.0290				
C19	0.9927	0.0073	2.1900	0.0330	0.0723				
C20	0.9952	0.0048	2.4400	0.0218	0.0532				
C21	0.9978	0.0022	1.9500	0.0099	0.0193				
C22	0.9943	0.0057	4.0100	0.0257	0.1031				

than 400 yuan to the current 14,000 yuan. The government benefits farmers and herdsmen through comprehensive measures such as letting farmers and herdsmen circulate sand to plant grass and trees, build infrastructure, government support, employment assistance, and education and training. Three new immigrant villages in Hangjin Banner, Yanhaizi, Daotugacha, and Hangjinnaoer have been built successively, with 333 households and 840 people of ecological immigrants [19]. The ecological behavior of the public in the sandy areas started in 1980 with the government's decision of "vegetation construction is the largest infrastructure construction" and the "decision to plant trees, grasses, and caragana korshinskii with 1 million mu each year." At this stage, numerous professional afforestation households have emerged.

By the end of the 1990s, under the guidance of the government, the public began to participate in the construction of the "desert-crossing highway" (Hangjin Banner Desert-Crossing Highway, also known as the Poverty Alleviation and Development Highway from Xini Town to Wulashan Town), with a total length of 115 kilometers. After entering 2000, the government-supported and encouraged farmers and herdsmen to carry out joint-stock development, taking the form of operation or participation of enterprises + bases and companies + farmers and herdsmen, extending the land contract period and service life, and auctioning them at low prices. The government also adopted free allocation of sandy land to large households for governance, exempted 3-5 years of fees, and allowed inheritance and transformation of sandy land after development. It also implements regular tax reductions and exemptions for the agricultural and sideline products processing industries of the people in the sandy area to guide the public become the main participants in the governance of Kubuqi. Only during the Tenth Five-Year Plan of China period, 713 large households with more than 500 acres of sand control and afforestation were formed, including Wurigendalai and Feng Zhiting. These people have afforested an area of 1.02 million mu, accounting for 20% of the total afforestation area in Ordos City (Qi Hailin, 2017) [5]. Based on consolidating the achievements of economic and ecological behavior construction, we should strengthen the perception of ecological effects. The ecological awareness weight and score are the lowest 10.51% and 0.0291. The research team found that farmers and herdsmen living in desert areas participated more in governance, while the public participation far from the desert areas was less.

3.2.3. First-Level Index Results. The comprehensive evaluation result is 0.8054 (Table 6), which is in the first grade, and the effect is excellent. In general, under the guidance of the ecological projects and policies of the central, autonomous region, and local governments, the ecological conditions of the Kubuqi Desert have achieved historical changes. In particular, since 2012, practicing Xi Jinxing's ecological civilization thought and the idea that "clear waters and green mountains are as good as mountains of gold and silver," we promote green transformation and development and implement the policy of giving priority to conservation, protection, and natural restoration, providing necessary conditions for governance.

3.3. Evaluation Results of the Public in Different Regions. The public comprehensive evaluation results of the two regions are similar (Figure 5). Hangjin Banner is 0.8209 and Dalate Banner is 0.8558, both in the first grade with excellent results. From their respective composition, the evaluation of each part of Dalate Banner is relatively balanced. In terms of public ecological behavior and public ecological awareness, the public in Hangjin Banner is slightly higher than the public in Dalate Banner, which is related to the main distribution of the Kubuqi Desert in Hangjin Banner. As a result, the public has an intuitive comparison and more active participation in increasing various incomes before and after governance.

3.4. Evaluation Differences of Different Public Heterogeneity

3.4.1. Independent Variable Diagnosis. Ten public attributes such as gender, age, and educational level are selected as independent variables. The public's evaluation of the government's ecological environment governance effect is used as the dependent variable. After the stepwise regression of the above indicators, the explanatory power of education level, household population, household category, annual crop income, annual breeding income, and annual other income is weak and not significantly so eliminated. R^2 in Table 7 is 0.223, meaning that gender, age, ethnicity, and occupation can explain 22.3% of the change in the public's evaluation of the government's eco-environmental governance effect. The model passed the F-test ($F = 24.559$, $p < 0.001$). The VIF values are all less than 5, there is no collinearity problem, the D-W value is near the number 2, there is no autocorrelation, and there is no correlation between the sample data.

For heteroscedasticity, two methods of the White test and the BP test are used to test. The null test hypothesis is that the model has no heteroscedasticity, which shows that both tests accept the null hypothesis ($p > 0.05$), and there is no heteroscedasticity problem (Table 8).

3.4.2. OLS Regression Results. In OLS regression (Table 9), the regression coefficient value of gender is 0.552 and passes the significance of 0.01, producing a significant positive correlation. It shows that gender has a greater impact on the public's evaluation of ecological governance results. Compared with female respondents, male respondents have a higher evaluation of governance effects. It may be that men are more sensitive to and concerned about policies than women and have a more objective judgment on implementing policies. In contrast, women often rely on intuitive feelings. The age passes the significance of 0.01, and the coefficient is negative, indicating that the older the age, the lower the evaluation of the effect of ecological governance. The national regression coefficient value is −0.308; through the significance of 0.05, there is a significant negative correlation. The regression coefficient value of occupation is −0.113, passing the significance of 0.01, which produces a significant negative correlation.

3.4.3. Quantile Regression Results. In quantile regression (Table 9), the regression coefficient of gender at the 50% quantile is the highest at 0.714. The quantile 25% and 50% pass the 0.01 significance test, and the 75% quantile pass the 0.05 significance test. The regression coefficient of age is the highest at the 50% quantile −0.357, and each quantile passed the significance test of 0.01. The regression coefficient of nationality is the highest at the 50% quantile −0.357, which passes the significance test of 0.05, and the other quantiles pass the significance test of 0.01. The regression coefficient of occupation rose from −0.200 to −0.000 and only passed the significance test of 0.01 at the 25% quantile, while the other quantiles were not significant.

4. Discussion

The research results in this article show that the ecological awareness weight and score are the lowest. Therefore, even in advanced new technologies, the ecological environment is essential for human coexistence and development. This is "too rich nature makes people inseparable from the hands of nature, just like children cannot do without the lead belt." [20] To resolve this contradiction, it is necessary to strengthen the ecological consciousness of the people in it, that is, environmental problems originate from the behaviors caused by people's misconceptions and consciousness, and the ecological environment governance is actually the governance of people. The public is the micromain body of Kubuqi governance and the driving force to promote sustainable environmental governance. However, according to research findings, Kubuqi's ecological governance is still in an embarrassing situation where the majority of people benefit from government-led support and a few people participation. First of all, farmers and herdsmen living in the desert area are doing their best for the management of the Kubuqi Desert, while the public far away from the desert area lacks the awareness and enthusiasm to participate in the ecological environment management and even thinks that it has nothing to do with them, which leads to the overall governance efforts are not enough. Secondly, governance activities are formalized and the channels through which the public can participate in governance are relatively simple. For example, civil servants and enterprise employees of the local government administration department of Hangjin Banner participate in tree planting and greening every year only through the tree planting day and tree planting week organized by the local government or party organizations' day activities. It is inevitable to be absent from time to time in the governance process, and the ecological awareness and

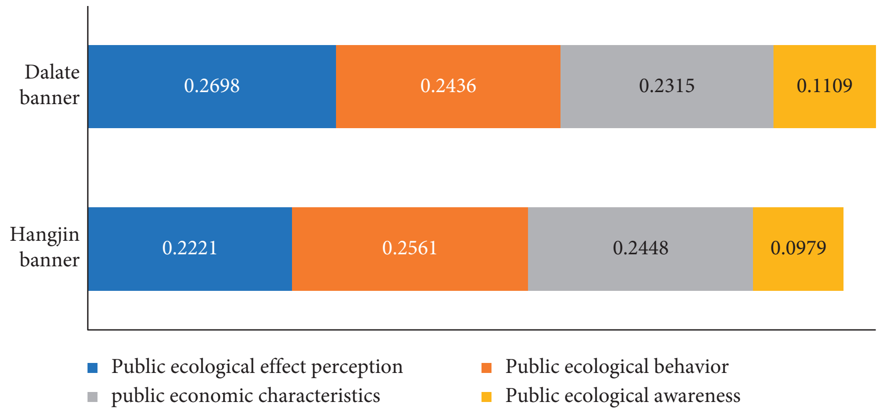

FIGURE 5: Comparison of public evaluation results between Hangjin Banner and Dalate Banner.

TABLE 7: Results of stepwise regression analysis.

	Regression coefficient	95% CI	VIF
Constant	4.339** (11.262)	3.584~5.094	–
Gender	0.568** (3.971)	0.288~0.849	1.093
Age	−0.384** (−7.449)	−0.484 ~ −0.283	1.156
Nationality	−0.328* (−2.498)	−0.586 ~ −0.071	1.012
Profession	−0.088** (−2.839)	−0.149 ~ −0.027	1.075
Sample size		347	
R^2		0.223	
Adjust R^2		0.214	
F value		$F(4,342) = 24.559$, $p \leq 0.001$	

D-W value: 1.752, * $p < 0.05$ and ** $p < 0.01$, and T value in parentheses.

TABLE 8: Results of the heteroscedasticity test.

White heteroscedasticity test		BP heteroscedasticity test	
χ^2	p	χ^2	p
15.375	0.636	2.454	0.783

TABLE 9: Comparison of OLS regression and quantile regression results.

	OLS	Quantile 25%	Quantile 50%	Quantile 75%
Constant	3.930** (7.991)	4.000** (8.847)	3.857** (8.416)	5.500** (9.271)
Gender	0.552** (3.846)	0.600** (3.660)	0.714** (4.195)	0.500* (2.396)
Age	−0.332** (−5.155)	−0.400** (−7.073)	−0.357** (−5.831)	−0.500** (−6.667)
Nationality	−0.308* (−5.155)	−0.400** (−2.747)	−0.357* (−2.284)	−0.500** (−2.669)
Profession	−0.113** (−3.126)	−0.200** (−5.382)	−0.071 (−1.932)	−0.000 (−0.000)
Sample size	347	347	347	347
R^2	0.227	0.074	0.166	0.101

*denotes $p < 0.05$, **denotes $p < 0.01$, and T value is in parentheses

sense of responsibility are weak. Therefore, the government should conduct targeted and dynamic propaganda against these groups [21], cultivating personal ecological consensus and reshaping ecological concepts.

In addition, obtaining governance policy information is an important criterion for the public to evaluate governance. Therefore, an open and transparent information-sharing mechanism should be embedded in the policy system to break the information "islands" between different subjects and different fields for "sharing governance" and two-way communication [22]. Moreover, it has a smooth information dissemination system to ensure the objective authenticity of its dissemination of information. There should also be a mechanism for other subjects' normal participation and institutional guarantees for classifying, solving, and responding to problems based on multiparty induction and integration. This can encourage the establishment of an institutional trust system between environmental information among various subjects and enhance the effectiveness of environmental governance.

Furthermore, suppose the government increases the transparency of its operations and allows other subjects to express policy preferences and dissatisfaction through various channels. In that case, people will increase their confidence in the political system's fairness, stability, and predictability. In turn, confidence in the system can enhance people's sense of trust in each other [23]. "The role of trust is like a lubricant; it makes the operation of groups or organizations more effective [24]," thereby promoting Kubuqi ecological governance affairs.

5. Conclusion

(1) The analysis of the third-level index shows that the public believes that the government's ecological governance measures have achieved good results. The ecological environment in the desert area has been significantly improved. The survival rate of trees has increased, the area of vegetation coverage and vegetation types has increased, and the frequency of sandstorms has decreased. However, the intensity of sandstorms and water flow is not a significant change. The various types of public income have increased significantly compared to before the governance. The public takes the ecological priority as the concept and actively participates in the government's governance implementation, which means that the ecological awareness and behavior are higher.

(2) In the second-level index, the weights and scores in the descending order are public economic characteristics 45.53% and 0.4840, public ecological behavior 25.62% and 0.1682, ecological effect perception 18.35% and 0.1240, and public ecological awareness 10.51% and 0.0291. The comprehensive evaluation result is 0.8054, the grade is 1, and the effect is excellent.

(3) The public comprehensive evaluation results of the two regions are similar, with Hangjin Banner being 0.8209 and Dalate Banner being 0.8557.

(4) In the OLS regression results, gender has a significant positive impact on evaluating the government's ecological environment governance effect. Age, ethnicity, and occupation have a significant negative impact. As the quintile increases, the influence of gender, age, and ethnicity first increases and then decreases. The maximum regression coefficient of gender at the 50% quantile is 0.714, which has a significant positive effect. Age has a significant negative impact at each quantile. The regression coefficient of ethnicity at the 50% quantile is the highest -0.357, which has a significant negative impact. Occupation only has a significant negative impact at the low quintile.

Data Availability

The data used to support the findings of this study can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Construction of University Online Examination System Based on Cloud Computing Technology

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With cloud computing's powerful computing power, many end users can create a variety of effective network applications using the cloud's services without having to worry about computing technology or access methods. Based on CC technology's on-demand service characteristics and unlimited dynamic expansion capability, this article designs and implements a shared network examination system. In the Web mode, the functions of receiving and distributing examination data, identity verification, online examination, and examination result collection can be realized using the SaaS deployment structure, MVC three-tier architecture, Java modeling language, XFIE, JSON, web service, DES, and other technologies combined with MySQL database. At the same time, the improved parallel genetic annealing algorithm (IPGAA) is proposed as a CC resource scheduling strategy. The IPGAA has better adaptability in the CC system with various cloud resources because it combines the fast global search ability of the genetic algorithm (GA) with the local search ability of the simulated annealing algorithm. Simulation tests show that the IPGAA is effective.

1. Introduction

With the application of various modern information technologies and the rapid development of network technology, many schools or institutions have gradually replaced the traditional paper examinations with online examination systems, thus improving the examination efficiency and the examination quality, and making the examinations no longer restricted by places and regions [1]. The existing online examination system structure modes mainly include client/server (C/S) structure and browser/server (B/S) structure [2, 3]. For the examination system with the C/S structure, the examination center is independent. During the examination, the administrator pushes the examination questions and examinee information down to the examination center, and the examinee takes the examination at the examination center. This kind of structure is mainly distributed in the local area network, and candidates can only take exams in the prescribed environment, which is limited to a certain extent in time and space. In addition, this kind of system has limited carrying capacity, is not easy to expand, and is easy to cause candidates' answers to be lost in emergencies, and there are some phenomena such as disconnected examination systems and difficult data synchronization, which makes it difficult for examination systems based on the B/S structure to be widely used. Therefore, a new technology is urgently needed to improve this dilemma [4].

Cloud computing (CC) is the product of the rapid development of the new generation Internet technology and is a new neural computing mode [5–7]. CC makes computing distributed on a large number of distributed computers, instead of local computers or remote servers. CC is the product of the integration and development of distributed computing, utility computing, virtualization technology, web services, grid computing, and other technologies. Its goal is that users can use virtual resource pools to the maximum at any time and any place through the network to deal with large-scale computing problems [8]. SaaS (software as a service) is one of the services provided by CC, which is a software application mode that provides software services based on the Internet, and represents the latest trend of software technology development [9, 10]. At the same time, double cache technology and adapter technology are used to help solve the problems of the examinee's answer loss and data synchronization among the examination systems under unexpected circumstances. Therefore, CC provides a technical solution for the design of the current online examination system.

The design of an online examination system based on CC in this article refers to the actual needs, given the rapid advancement of CC technology and the rapid development of the economy. The system can help enterprises enjoy high concurrent examination services at a lower cost, and distributed examination services can be configured at any time according to the needs of examination scale, reducing the pressure on the main system, increasing the concurrent number, and providing a stable and reliable platform for large-scale online examinations, thanks to CCs unlimited dynamic expansion capability.

The main innovations of this article are as follows:

(1) According to the functions of the system, aiming at the problems that the traditional random algorithm has weak control ability on knowledge points and difficulty in generating test papers, and low efficiency caused by a large number of repeated invalid test questions, an improved random test paper generating algorithm based on knowledge points and difficulty is proposed for job generation.

(2) A cloud computing resource scheduling strategy based on IPGAA is proposed. It solves the problems of single-point failure, high communication overhead, and relatively low efficiency of scheduling algorithm in existing resource scheduling.

2. Related Work

CC and its applications are rapidly developing and expanding as a result of the academic and industrial communities' understanding of it, affirmation of its role, and joint promotion of its technology. Literature [11] connects data in a new way, adjusting and improving them at the same time, ensuring their independence, addressing user and cloud security, and integrating resource usage, which is a secure new cloud security technology. Literature [12] demonstrates that through Hadoop, "cloud" can execute parallel applications on huge datasets in a reasonable time, thus supporting computation-intensive services. Literature [13] studies the secure storage of CC and proposes a recoverable proof model to ensure the recoverability and error correction performance of data. Literature [14] puts forward a method to integrate the virtual machine model into the existing resource management framework. Using a two-level scheduling method, virtual machine management will be integrated into batch scheduling to provide better scheduling services for cloud users. However, at present, reservation services for virtual resources are not supported. Literature [15] puts forward a method of automatically and quickly deploying context, which is mainly realized by analyzing the context environment of a virtual cluster, such as IP address of a virtual machine and security information. In addition, a virtual private network provides a customizable network environment for cloud users.

Because system parameters such as CPU time and virtual machine memory size are not independent of one another in a CC system, the impact of system parameters on performance is frequently nonmonotonic. Classic optimization algorithms are rarely used in online parameter configuration because of their high time complexity. Literature [16] automatically manages resources based on self-management strategy and describes how to coordinate according to policies and messages. Literature [17] proposes a CC virtual resource allocation algorithm based on the ant colony algorithm. The algorithm gets better quality and response time, but it can only be used to search computing resources and is limited in the simulation stage. Literature [18] studies the application of CC technology in smart grid, introduces CC technology into traditional smart grid technology, puts forward the idea of intelligent cloud, and makes in-depth research along with the construction of intelligent cloud, resource management, and corresponding security mechanism. Literature [19] puts forward a resource allocation and pricing strategy based on particle swarm optimization. Literature [20, 21] suggests that the feedback control method can be used in the CC system to complete the adaptive configuration and dynamic resource allocation of virtual machines.

3. Research Method

Based on CC technology, the university online examination system studied in this article uses the algorithm for generating test papers. At the same time, a genetic annealing algorithm with double fitness is proposed, which enables the cloud computing system to dynamically formulate cloud resource scheduling solutions to meet the cloud resource requirements of different cloud users and ensure the response time of the cloud computing system to cloud user requests.

3.1. Overall Design of the System

3.1.1. Overall Business Architecture of Cloud Examination System. Cloud examination system is based on CC service, aiming at realizing "on-demand" subscription. Its design and development require scalability and foresight, and it must be able to exchange data with other existing systems. As an independent system, the cloud examination system will provide multiple interfaces to obtain reference personnel and examination information. Besides feeding back the examination results to external systems, it can also provide comprehensive examination information. The overall business structure is shown in Figure 1.

The external subsystem, examination subsystem, examination information input interface, examination login interface, examination result feedback interface, and monitoring information query interface are shown in Figure 1. The entire business architecture is divided into two subsystems and four interfaces: external subsystem, examination subsystem, examination information input interface, examination login

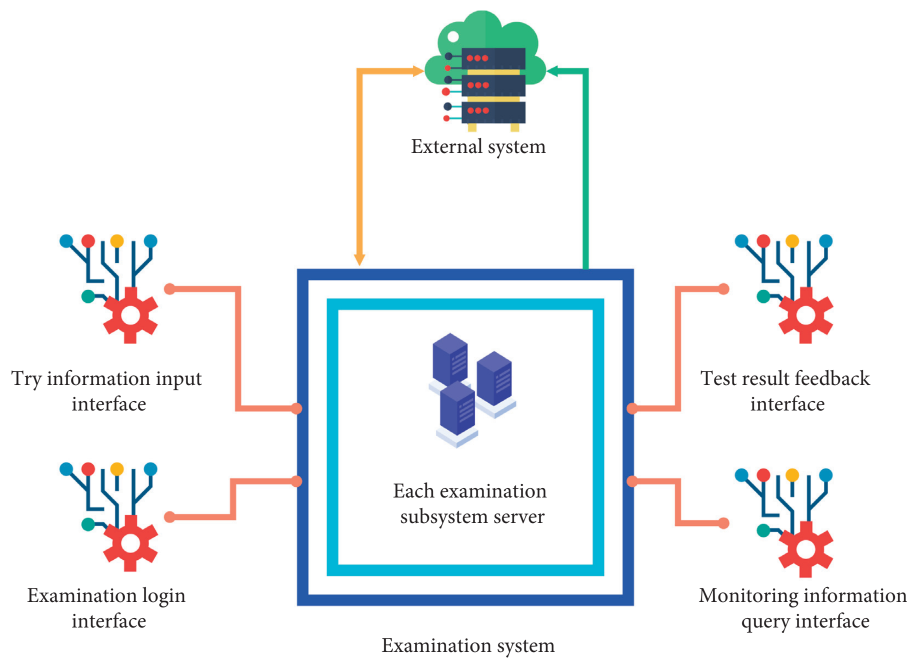

Figure 1: Overall business architecture diagram of the cloud examination system.

interface, examination result feedback interface, and monitoring information query interface. A detailed description of the subsystems and interfaces is given as follows:

(1) *External system:* Peripheral subsystem refers to all systems that need examination services. The number of these subsystems is unlimited and can be expanded as needed to achieve the purpose of customizing examination services.

(2) *Examination system:* Examination system is a system that provides examination services for the periphery. The examination server uses distributed deployment, adopts the shortest path principle to route and forward the examination service request of the external system, and obtains the nearest normal server to process the request.

(3) *Examination information input interface:* The examination subsystem obtains the basic information of the examinees, examination papers, and so on through the examination information input interface.

(4) *Test result feedback interface:* The test result feedback interface is that the test system feeds back the test results to the peripheral system.

(5) *Examination login interface:* The login interface is a separate entrance of examination service provided by the examination system, through which reference personnel can directly enter the examination system for examination without logging into the peripheral system.

(6) *Monitoring information query interface:* The information query interface is an internal interface of the examination system, which is mainly used to monitor the running status of each server of the examination system and provide reference for routing and forwarding.

3.1.2. System Function Module Design. According to the demand analysis of the online homework and examination system, the whole system is divided into two subsystems: homework system and examination system. The Homework subsystem is composed of student module and teacher module, which mainly completes three functions: students' independent training, online work, and test paper generation.

The periodic examination function is performed by the examination subsystem. For example, a teacher may send out an examination notice instructing students to complete a paperless mid-term examination with the specified difficulty coefficient, number of questions, and time limit. Teachers can dynamically understand students' weak links in the course learning process, strengthen students' training on weak knowledge points, and realize intelligent guidance of autonomous learning based on homework feedback.

Figure 2 shows the design of the total functional modules of the system.

3.1.3. Design and Implementation of Database. Online homework and examination system is an application system based on database, in which user information, question bank information, and test paper information are stored. In fact, the database design of this system is to design the structure of every two-dimensional table stored in the database. The system includes two subsystems: homework and exam. It is necessary to design a table for storing exam information, as well as a table for each user's homework information, exam information, and score information. Because the system has

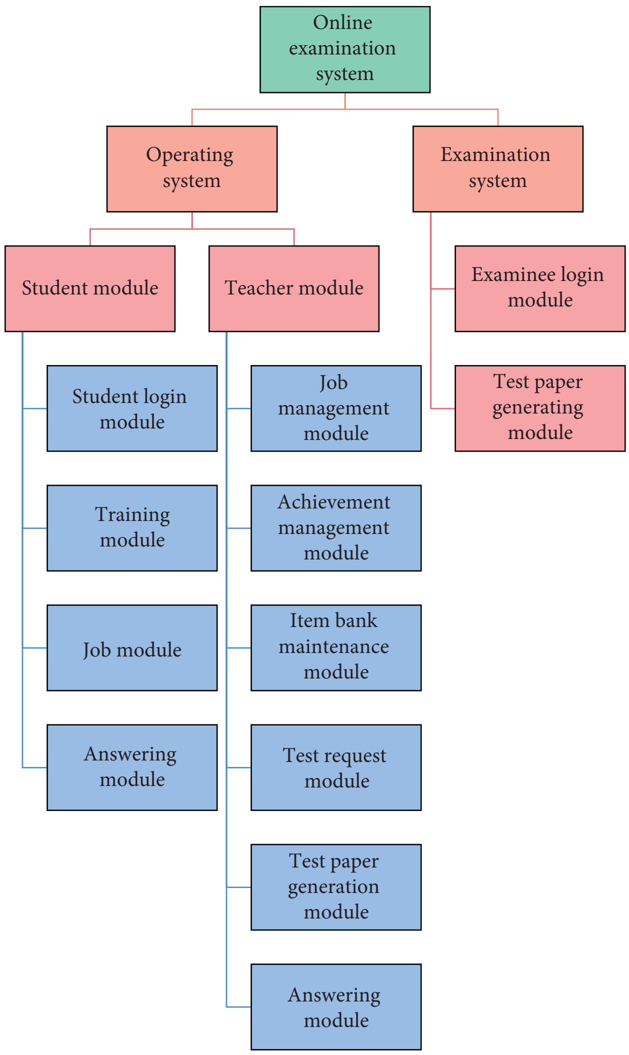

Figure 2: Total functional modules of the system.

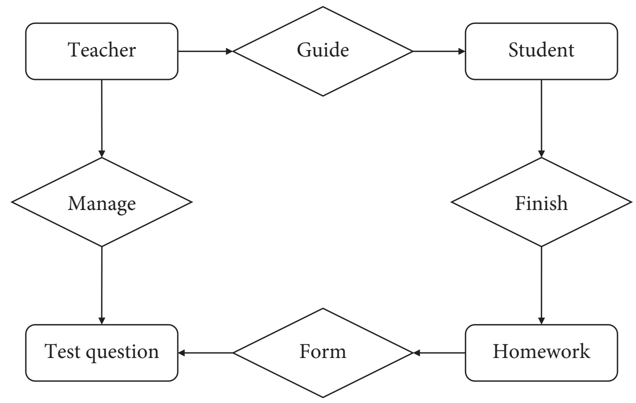

Figure 3: Entity relation diagram.

the function of answering questions online, it is necessary to design a table for storing questions and replies.

According to the results of requirement analysis, conceptual design uses conceptual data model to express the relationship between data and requirements. This model has nothing to do with the database management system, is universal [22], is independent of computer software and hardware systems, and is very convenient to communicate with users. Through the analysis of system requirements, the entities such as students, teachers, test questions and assignments, and their relationships are designed. The E-R diagram of the relationship among students, teachers, homework, and test questions is shown in Figure 3.

3.2. Research on Key Technologies of System Development

3.2.1. System Development Environment. This system adopts MVC (model-view-controller) three-tier architecture mode (namely, presentation layer, business logic layer, and data access layer logic) and is written in the Java language. As Java is an object-oriented cross-platform language, this system can be applied to many operating systems such as Windows and Linux. During the development of the system, the following key technologies are involved:

(1) ActiveMQ is Apache's open-source message stack. The system mainly uses ActiveMQ to share some data transmission and relieve the pressure on the database. Data enters the queue first and then the queue stores the data in the database.

(2) Encryption technology of DES (data encryption standard). It is used to transmit important data, and all passwords of users in the database are encrypted by DES, which improves the security of the system.

(3) XFire is the Java web service engine. It can easily publish the web service interface for other programs to call.

(4) MyBatis is the persistence layer framework. It can easily map Java objects into database records by annotation, write SQL code in XML (Extensible Markup Language), and separate it from Java code, which is beneficial to the maintenance of the system.

(5) JSON (JavaScript Object Notation) is a lightweight data interactive format, which is easy for programmers to read and write, and also easy for computers to parse and generate.

3.2.2. Test Paper Generation Algorithm. The users of online homework and examination system are students and teachers. For students, the purpose of homework and examination is to test their mastery of knowledge, while teachers judge students' mastery of course content through students' training and submitted homework, and adjust teaching plans appropriately. The algorithm for generating test paper should be reasonable, fair, and scientific.

The process of generating test papers is to select appropriate parameters, and according to a certain strategy of generating test papers, select the test questions that meet the requirements from the test question bank to form a test paper. The process of volume formation has the following steps, as shown in Figure 4.

Explain the process of generating test paper as follows:

(1) Because this strategy is used for homework and test paper generation, the requirements of these two

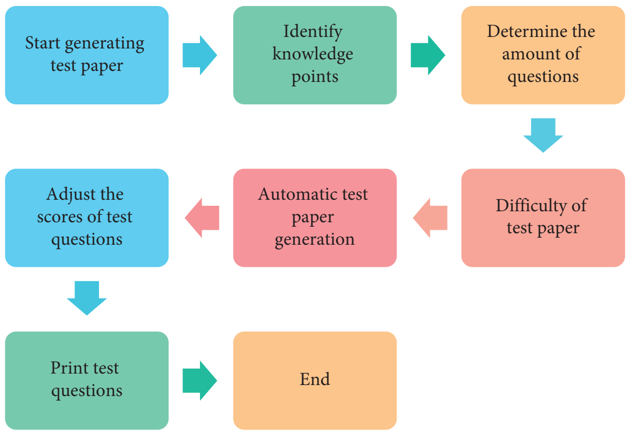

FIGURE 4: Basic steps of volume formation.

operations are different. When the job is generated, the score is not determined and adjusted.

(2) When determining the number of questions, considering that the examination time is limited, an appropriate number of questions should be arranged.

(3) The purpose of adjusting test scores is to make the test scores more reasonable. Teachers can adjust the test scores slightly according to the difficulty of the test questions when the total score is 100.

Test paper is the process of making the selected test attributes meet these conditions according to the constraint conditions. Specifically, it can be understood that the test paper consists of m test questions, and each question has 7 attributes to meet, which are represented by a $m * 7$ matrix:

$$S = \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{17} \\ s_{21} & s_{22} & \cdots & s_{27} \\ \vdots & \vdots & \ddots & \vdots \\ s_{m1} & s_{m2} & \cdots & s_{m7} \end{bmatrix}. \quad (1)$$

In the above matrix, each line represents a test question, and $s_{i1} - s_{i7}$ corresponds to the attributes in the test question attribute table, namely, question number s_{i1}, question type s_{i2}, chapter s_{i3}, difficulty coefficient s_{i4}, discrimination s_{i5}, test question score s_{i6}, and secondary knowledge point s_{i7}. The matrix should satisfy the following Jordan conditions:

Knowledge point constraint:

$$Z_j = \sum s_{i3} * c_{1i}, \quad c_{1i} = \begin{cases} 1, & s_{i3} = j, \\ 0, & s_{i3} = 0. \end{cases} \quad (2)$$

The test questions belong to the first j knowledge point, the chapter points plus 1.

Question constraint:

According to the characteristics of the course of communication electronic circuit, the types of test questions are set as selection, filling in the blanks, short answers, and calculation. In the process of grouping questions, the structure of test questions is fixed. $T = (T_1, T_2, T_3, T_4)$ is used to represent, where T_i is the number of different types of questions, and the calculating formula is

$$T_i = \sum s_{i2} * c_{2i}, \quad c_{2i} = \begin{cases} 1, & s_{i2} = i, \\ 0, & s_{i2} \neq i. \end{cases} \quad (3)$$

Total score constraint:

The total score of a test paper can be expressed as $ZF = \sum s_{i6}$, and the default full score is 100.

Difficulty constraint:

The difficulty factor G is expressed as

$$G = 1 - \frac{\sum s_{i4}}{m}. \quad (4)$$

The problem of creating test paper is essentially a multi-constraint combinatorial optimization problem. Many constraints, such as question type, knowledge point, and difficulty, must be met in order to generate a reasonable and scientific test paper. These issues are intertwined. When creating test paper, different weights are assigned based on the importance of each attribute, in order to meet as many constraints as possible.

Define the overall error $F(x)$ of the test paper, which is equal to the error value $e_i(x)$ of each index multiplied by their weight value W_i, and the final ideal result is that the error value is simplified to the minimum value problem of $F(x)$ as much as possible, that is,

$$\min F(x) = \sum_{i}^{4} W_i e_i(x). \quad (5)$$

3.2.3. CC Resource Scheduling. The distribution, heterogeneity, and dynamics of CC resources determine the complexity of the CC resource scheduling system. Therefore, the research on cloud resource scheduling has become another key issue in the CC system. To solve the above problems, this study proposes a CC resource scheduling strategy based on the improved parallel genetic annual algorithm (IPGAA). Figure 5 shows the specific algorithm flow. It enables the CC system to dynamically formulate cloud resource scheduling solutions to meet the cloud resource requirements of different cloud users, while ensuring the response time of the CC system to cloud user requests.

According to the optimal solution scheme, cloud users can request effective scheduling of available cloud resources in the CC system, which makes the resources of the whole CC system be scheduled in a balanced way and effectively improves the efficiency of the whole system.

A virtual machine resource can be described by a sextuple, as shown in the following formula:

$$V = \{\mathrm{ID}, \mathrm{CPU}, \mathrm{Ram}, BW, F, P\}. \quad (6)$$

The type, ID represents the virtual machine's unique identifying number; CPU represents the number of virtual CPUs in the CC system; Ram represents the memory size of virtual machines in the CC system; BW represents the maximum bandwidth allowed by virtual machines in the CC system; F represents the failure rate of virtual machines in the CC system; and P represents the price of using virtual machines per unit time in the CC system.

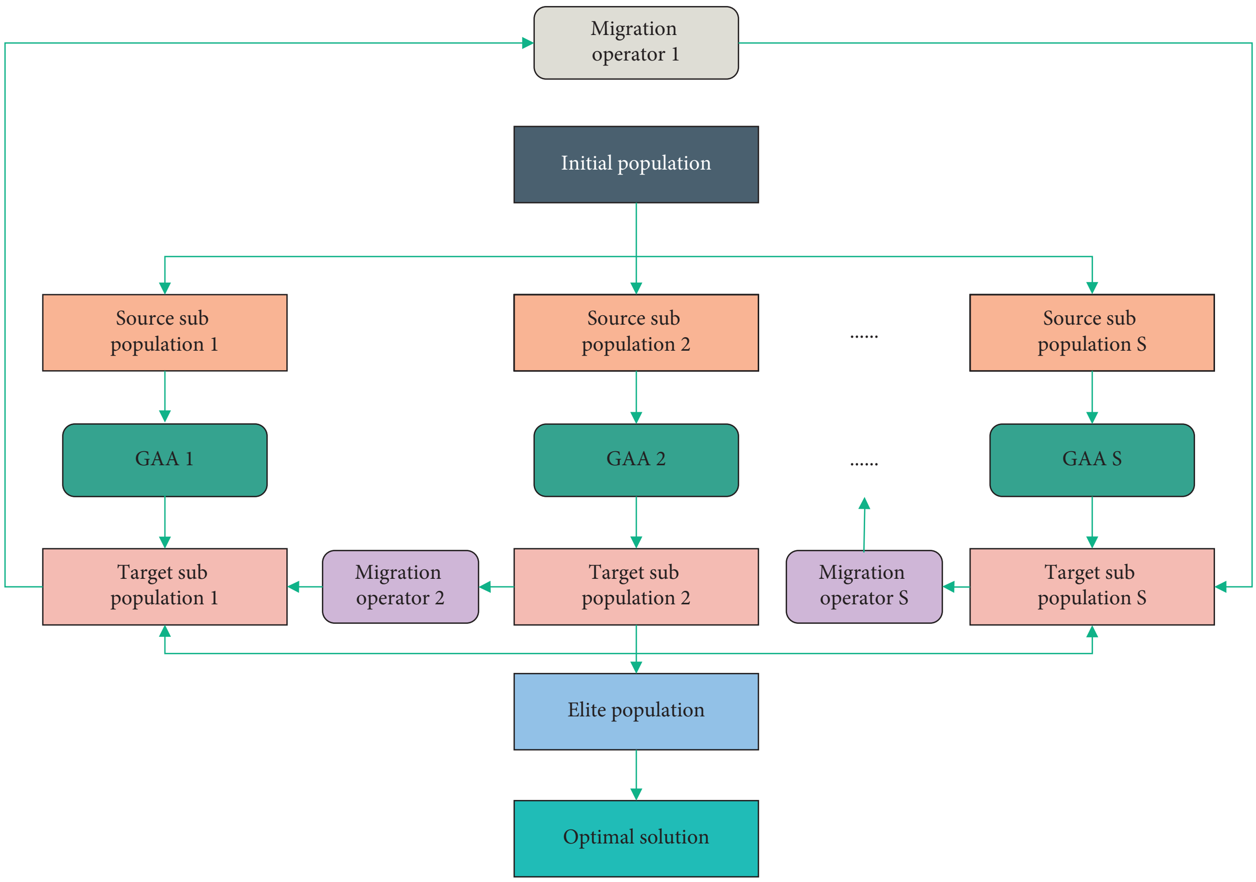

Figure 5: Parallel genetic annealing algorithm process.

According to the characteristics of resource scheduling in the CC system, this study proposes to encode the available cloud resources occupied by each cloud user's subtasks by indirect encoding. Figure 6 shows the coding method used in this study, and its specific coding scheme is as follows: the position number of each bit of chromosome indicates the number of cloud user subtasks; chromosome represents the number of available resources occupied by cloud user subtasks, which is represented by the positive integer value of each bit.

In Figure 6, T_i represents the number of cloud user subtasks and R_i represents the number of available cloud resources occupied when executing the cloud subscriber subtask T_i.

The total completion time of all cloud subscriber request tasks running on a virtual machine is the virtual machine's cloud subscriber task execution time. As a result, the total completion time required to run all cloud user tasks in the entire CC system is equal to the maximum running time of all virtual machines running cloud user tasks, that is,

$$F(x) = \operatorname*{Max}_{m=1}^{M} \sum_{i=1}^{n} \mathrm{Time}(m, t). \tag{7}$$

In the above formula, $\mathrm{Time}(m, t)$ represents the time required to execute the t-th cloud user task on the virtual machine with the identification number of m; n represents the number of cloud user tasks running on the virtual machine labeled m; and M indicates the total number of running virtual machines in the CC system.

T_1	T_2	T_3	...	T_n
R_1	R_2	R_3	...	R_n

Figure 6: Coded system.

The operation of the selection operator of the IPGAA algorithm proposed in this study is realized by roulette model; that is, the selection probability of each individual is proportional to the value of its fitness, and $P(i)$ is used to represent the selection probability of individuals; then,

$$P(i) = \frac{F(i)}{\sum_{i=1}^{\text{popsize}} F(i)}. \tag{8}$$

It should be pointed out that in the IPGAA algorithm proposed in this study, the crossover probability P_c and mutation probability P_m are dynamically changed, and the P_c function and P_m function are

$$P_c = \begin{cases} \dfrac{k_1 (f_{\max} - f')}{(f_{\max} - f_{\min})}, & f' \geq f_{\text{avg}}, \\[2ex] \dfrac{k_2 (f_{\max} - f'')}{(f_{\max} - f_{\min})}, & f'' \leq f_{\text{avg}}, \end{cases}$$

$$P_m = \frac{k_3 (f_{max} - f)}{(f_{max} - f_{min})}. \tag{9}$$

The maximal fitness value of chromosomes in a modern evolutionary population is represented by type k_1, k_2, k_3, which is a constant; f_{max} represents the maximum fitness value of chromosomes in contemporary evolutionary population; f' indicates that the fitness of two chromosomes crossing in the contemporary evolutionary population is larger; f_{min} represents the minimum fitness value of chromosomes in contemporary evolutionary population; f_{avg} represents the average fitness value of all chromosomes in the contemporary evolutionary population; f' indicates that the fitness of two chromosomes crossing in contemporary evolutionary population is small; and f represents the fitness value of variant chromosomes in contemporary evolutionary population.

From the above analysis, it can be concluded that the IPGAA algorithm proposed in this study uses the indirect coding mode of "resource-task," and the process of redistributing cloud resources occupied by cloud users' tasks corresponds to the process that chromosomes in the population are operated by crossover and mutation operators to generate new chromosomes in the IPGAA algorithm. Therefore, the IPGAA algorithm is adopted to solve the resource scheduling problem in the CC system, which combines the characteristics of both, and provides an effective method for the resource scheduling problem in the CC system.

4. Result Analysis and Discussion

4.1. Test Paper Generating Results and Analysis. In order to test the improvement of GA on the performance of generating test paper, the following groups of experiments were performed, each experiment was conducted 20 times, the successful running time was averaged, and the algorithm success rate and knowledge points were counted.

Experiment: 6 multiple-choice questions, 7 fill-in-the-blank questions, 8 short-answer questions, and 5 calculation questions, with a difficulty coefficient of 0.55. Chapters: all chapters, select all secondary knowledge points, and the amount of question bank: 600;

Experiment 2 : 12 multiple-choice questions, 14 fill-in-the-blank questions, 15 short-answer questions, and 10 calculation questions, with a difficulty coefficient of 0.55. Chapters: all chapters, select all secondary knowledge points, and the amount of question bank is 600.

Experiments were conducted 20 times, and the results are shown in Figures 7 and 8.

Figures 7 and 8 show that, while the GA takes much longer than a random algorithm to generate test papers under the same conditions, its success rate has greatly improved, especially as the number of test banks and questions grows larger. It is worthwhile to sacrifice time for system applications in order to improve the success rate.

4.2. Map/Reduce Model Performance Analysis. Due to the limitation of experimental conditions, one Hadoop distributed platform is selected as the main server, and the remaining seven are node servers. Make relevant verification under the Linux environment. This study gives full consideration to the computing performance of each different computing node, the distance between map tasks, and the distance between the node and the master node. Map/reduce considers load balancing, but balanced allocation cannot. By taking the first 10 tasks in an average of 20 tests, we compare the accuracy of data results retrieved by one map/reduce model and two map/reduce models, as shown in Figure 9.

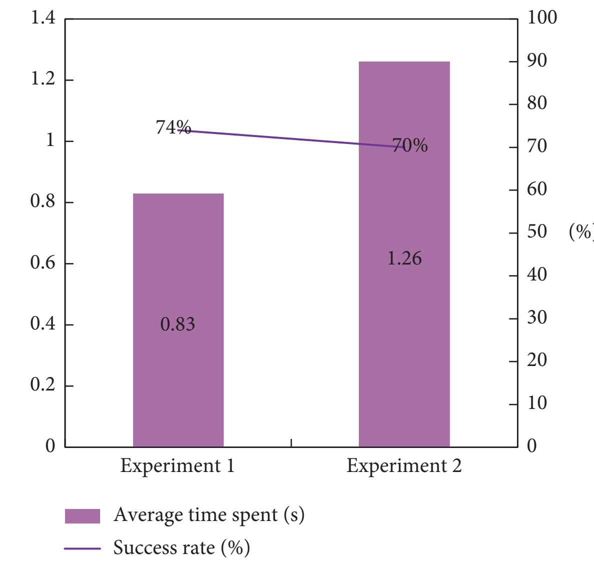

Figure 7: Success rate and time consumption of random test paper generation.

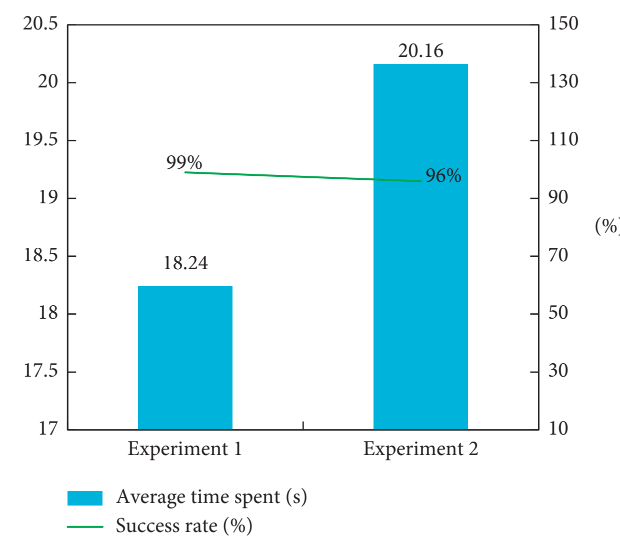

Figure 8: GA test paper generation success rate and time consumption.

While the secondary map/reduce classified storage ensures the time efficiency of tasks, its index retrieval effect in the secondary classified storage is obviously better than that in the primary map/reduce model. The reason for this is that the primary map/reduce has too much data and too many

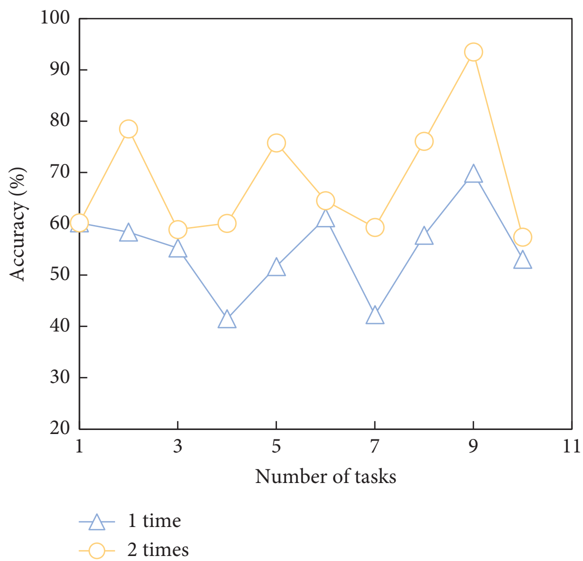

Figure 9: Search graph based on secondary map/reduce classified storage.

returned results, and the data results are often incomplete and inaccurate, resulting in a decline in users' interest.

However, the secondary map/reduce classified storage reduces the number of searches , improves the accuracy of returned results and the user satisfaction, and is more targeted.

4.3. Simulation Analysis. In order to prove the effectiveness and efficiency of the IPGAA algorithm proposed in this article, this article uses CC simulation tool CloudSim to conduct simulation experiments and chooses Cloudsim-3.0.2 version software. In the Cloudsim working model, cloud information service is responsible for allocating appropriate CC resources for user requests. Among them, the data center agent is responsible for the assignment of tasks to virtual machines. The virtual machine allocation control policy is responsible for completing the mapping between virtual machines and hosts. A virtual machine scheduler is an abstract class that implements host components and simulates the allocation and scheduling strategy of virtual machines.

This simulation is mainly an extension of DatacenterBroker, in which the IPGAA is introduced to realize the deployment of Task to the virtual machine.

There are t tasks $\text{Task} = \{\text{Task}_1, \text{Task}_2, \ldots, \text{Task}_t\}$ and m virtualized resources $VM = \{VM1, VM2, \ldots, VM_m\}$. The experiment simulates two groups of resource scheduling scenarios: the first group simulates 20 resources and 30/70/100 tasks, and the second group simulates 30 resources and 30/70/100 tasks. When the population size is set to 300 and divided into 6 subpopulations, the size of each subpopulation is $N = 50$.

Through a large number of simulation tests, Figure 10 shows the specific experimental results. In Figure 10, the algorithm completion time and algorithm evolution algebra

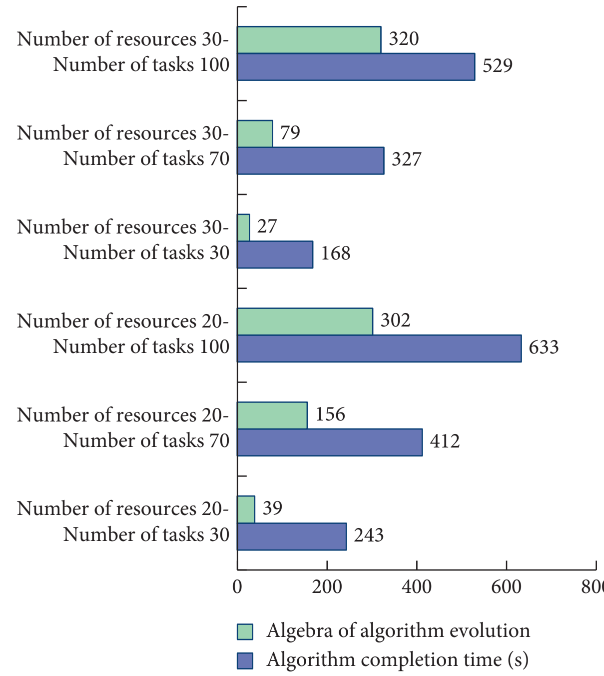

Figure 10: Simulation experimental results.

of the IPGAA algorithm are the average values obtained by running the algorithm 50 times.

It can be concluded from Figure 10 that when the number of cloud user tasks remains unchanged, for example, when the number of cloud user tasks $n = 30$, as the number of available cloud resources increases from 20 to 30, the completion time of the IPGAA algorithm decreases; when the number of cloud user tasks $n = 70$, with the increasing number of available cloud resources, that is, when the number of available resources increases from 20 to 30, the completion time of the IPGAA algorithm decreases greatly.

At the same time, Figure 10 shows that the number of cloud user tasks has increased from 30 to 70 and 100, and the algorithm completion time of the IPGAA algorithm shows an overall upward trend. However, the completion time of the algorithm did not increase exponentially with the number of cloud user tasks; on the contrary, it was a process in which the growth ratio was relatively reduced, which showed an optimization trend in essence. Similarly, when the number of available cloud resources is set to $m = 30$, a similar conclusion can be obtained.

Figure 11 lists the simulation execution results of the IPGAA algorithm under the conditions that the number of resources is $m = 20$ and $m = 30$, and the number of scheduled cloud user tasks is $n = 30$.

It can be concluded from Figure 10 that when the number of available cloud resources is set to $m = 20$ and the number of cloud user tasks is set to $n = 30$, the IPGAA algorithm converges to the global optimal solution around the 38th generation, and the solution of the average completion time of the IPGAA algorithm in each generation after the 38th generation is the same as that around the 38th

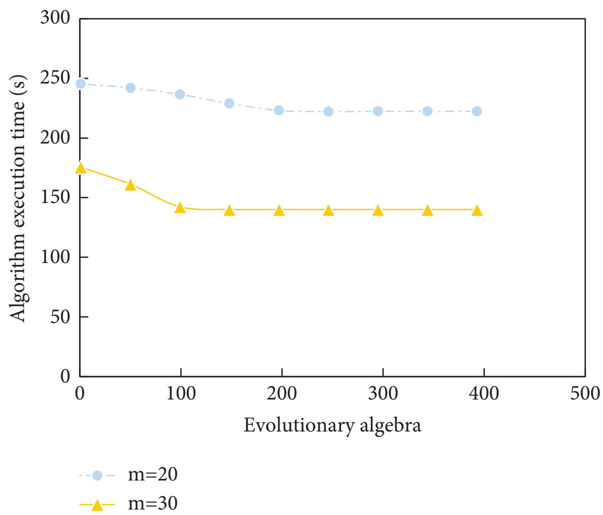

Figure 11: Algorithm simulation results.

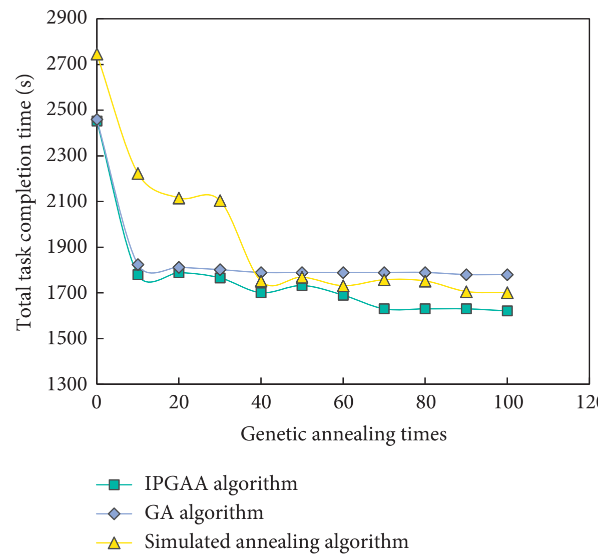

Figure 12: Comparison of total task completion time.

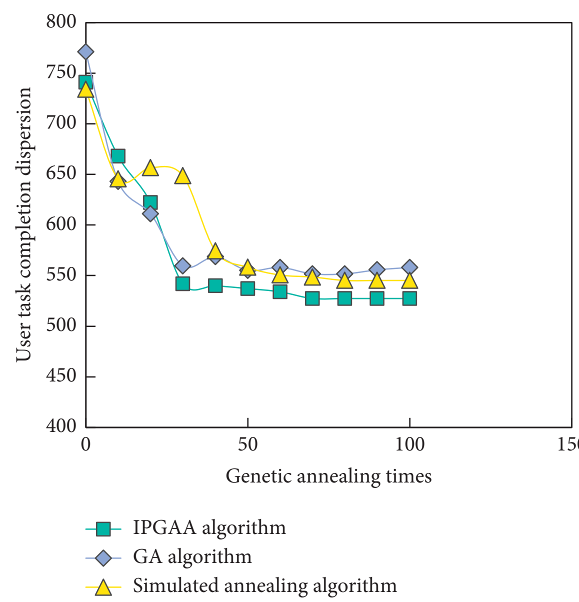

Figure 13: Cloud user task completion dispersion.

generation. Therefore, it can be concluded that the IPGAA algorithm is convergent and has good stability.

When the number of available cloud resources is set to $m = 30$ and the number of cloud user tasks is set to $n = 30$, the IPGAA algorithm converges to the global optimal solution when it runs to the 28th generation or so. And in the generations after the 28th generation, the solution of the average completion time of the IPGAA algorithm is the same as that in the 28th generation or so, and it can also be concluded that the IPGAA algorithm is convergent and has good stability.

In order to further verify the efficiency of the IPGAA algorithm proposed in this article, this article compares the IPGAA algorithm, simple GA algorithm, and simple simulated annealing algorithm, and compares the performance of these three algorithms in total task completion time and cloud user task completion dispersion. The performance comparison results of the above two aspects are shown in Figures 12 and 13.

It can be concluded from Figure 12 that for the total completion time of all cloud user tasks in the CC system, the final task completion time of three scheduling algorithms, that is, IPGAA algorithm, GA algorithm, and simulated annealing algorithm, is almost the same. However, compared with simulated annealing algorithm, the IPGAA algorithm shows that its convergence is better and faster.

This fully shows that IPGAA algorithm can not only get less total completion time of cloud user tasks, but also accept nonoptimal solutions with a certain probability, thus effectively avoiding local convergence caused by fast convergence of GA and greatly improving the performance of the cloud user task scheduling algorithm.

From Figure 13, it can be concluded that the convergence speed of the IPGAA algorithm is slower than that of GA because it can accept the nonoptimal solution of the IPGAA algorithm according to a certain probability.

In addition, the IPGAA algorithm can effectively prevent local convergence, and its final cloud user task completion dispersion is smaller than simple GA and simple simulated annealing algorithm. The smaller the dispersion of cloud user task completion, the higher the cloud user satisfaction, indicating that the IPGAA algorithm has achieved higher cloud user satisfaction than the other two algorithms.

5. Conclusion

Due to the closed, scattered, and uneven distribution of resources in the network examination system's application in enterprises, CC technology was introduced into the network examination system, which solved the problem of dynamic distribution of examination resources on demand, and successfully designed and implemented an online examination system based on CC. There were two subsystems created: online homework and online exams. The online homework module gives students the ability to do online practice and homework, which makes it easier for teachers to keep track of their students' homework and spot any leaks or gaps in their instruction. The IPGAA algorithm has better adaptability in the CC system with various cloud resources, as it introduces the basic idea of the genetic annealing algorithm, fully combining the fast global search ability of the GA and the local search ability of the simulated annealing algorithm.

Cloud technology requires a large number of users to participate, and privacy problems inevitably arise. Users' participation means collecting some user data, which leads to the worry about the safety of user data. Many users are worried that their privacy will be collected by cloud technology. For this reason, when joining the cloud plan, many vendors promise to avoid collecting user privacy as much as possible, and even if they do, they will not disclose or use it.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

A Study of Big-Data-Driven Data Visualization and Visual Communication Design Patterns

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This paper provides an in-depth study and analysis of big-data-driven data visualization and visual communication design models. The characteristics of new media and the definition of traditional media are analyzed; the importance of the new media environment is derived through comparison; and the successful cases of new media integration today are analyzed. In this process, we will optimize the traditional science and technology intelligence service model, optimize the various components that make up the science and technology intelligence wisdom service, achieve model optimization and reflect the four characteristics of science and technology intelligence wisdom service, and reconstruct the science and technology intelligence wisdom service using the literature research method. The design based on imagery schema theory is manifest, inclusive, and somewhat innovative and at the same time has a high degree of consistency and internal logical relationship with the visual representation of multidomain heterogeneous data at the cognitive level and displays purpose. This internal logical relationship is systematically organized and deeply analyzed, and the methodology from subpattern extraction and visual interaction design to the deep integration of visual representation is proposed in combination with specific application scenarios and cases.

1. Introduction

In the twenty-first century, digital information technology is the main media way. The major mode of communication in the new media environment of visual communication design is network communication, which is used to lead people to a new visual direction while connecting the orientation of consumerism culture, as the country continues to progress, in enhancing the hard strength of culture while also enhancing the soft power of culture. Therefore, under the continuous change of market economy, the transformation form of visual communication performance to meet the market is also particularly important, especially the expression form of visuals in the new media environment and the innovation of design style. This paper will also examine people's mainstream ideologies on the research and analysis of visual performance, as well as the audience group's psychological change features, popular aspects, and other varied factors [1]. In the market economy, we design to meet the consumer's psychology and activate the desire to buy, thus boosting the gross domestic product [2]. So this article will also analyze the research and analysis of people's mainstream ideology on visual performance that is very important and, at the same time, study various factors such as the psychological changes of the audience and popular elements. In the international design arena, design works not only follow the international fashion trend in the form of expression but also understand different aspects of domestic regional culture, customs, and folklore to regionalize to centralize the extraction of design works representing Chinese regional elements to the world. We should pay attention to both the embodiment of its value, but also should pay attention to the timeliness of the delivery of information published, the time of delivery, delivery efficiency, communication carriers, and the feelings of the audience [3]. In the digital information technology progress today, the form of design expression should also have the mass type. The cost of dissemination in new media operations is much more than the audience (which refers to the news media dissemination object as well as a variety of cultural and artistic works of the recipient) brought about by its dissemination itself and by economic benefits, so it cannot be formed for the effective value of the media.

In recent years, the rapid development of new media stage, the emergence of many new communication companies, but in the baptism through the media storm, few companies can survive; without understanding the core of the new media communication design expression form, blindly copying and borrowing other works leads to failure, or the design concept is too far beyond people's basic cognitive aesthetics which leads to design failure, such examples abound [4]. While choosing the essence and the dross, it is also important to grasp the timeliness, interactivity, and interactivity of new media. With the aid of technology and information technology, it is also important to reflect the transformation of visual performance in an innovative way. Therefore, designers should profoundly analyze the ideology of consumers and the psychology of the audience before designing works and should not impose difficult design concepts on the design performance, leading to the failure of design works and market inconsistency and disproportionate input and outcome. In the data-driven era, the data resources faced by scientific and technological intelligence services show multidimensional, heterogeneous, and massive trends. These trends make it difficult for traditional data analysis methods, techniques, or tools to cope with the current situation of multiple and heterogeneous data sources, which is one of the challenges faced by science and technology intelligence agencies. According to the task division of S&T intelligence services defining the time, scope, format, and processing techniques of multisource data, there are five key categories of S&T intelligence tasks such as identification tasks, tracking tasks, comparison tasks, evaluation tasks, and prediction tasks. Cartography plays an important role in geographic research, where the main use is for the scientific exploration of geographic laws. Initially, it was used as a visualization product for abstract thinking [5]. With the transformation of cartography from traditional paper maps to computer hardware facilities such as screens, the information-carrying capacity of maps and the accuracy of information expression are also increasing, and the ways of human interaction with maps for data analysis are also enriched. And with the continuous development of Internet technology, the public openness of geographic information services is getting higher and higher. The communication of web map information has also faced a variety of different user needs. The tools and workflows produced by online mapping platforms, as well as the interactive features that can be implemented, are categorized and summarized in a series of case studies of maps from government, academia, and research institutions. It is concluded that overall, the technical difficulty of online mapping is decreasing due to open data distribution, open-source software, and cloud service innovations. These new technologies are enabling increasingly powerful data exploration capabilities and are an important part of big data and open data. However, online analytics capabilities for the web are currently less mature and can have promising applications in areas such as urban analytics.

Process-based assessment with big data will record and analyze all data about the student learning process. It is the fusion of information related to learning outcomes that will aid in decisions about instructional improvement. Although teacher excellence is outcome-oriented, if the process is ignored, it is difficult to reproduce the growth process of teaching excellence and replicate more of them. The commercial benefits brought by the communication itself cannot be formed into the effective value of the media. For example, evaluating the computer technology and information literacy abilities of computer science majors and teacher education majors by testing their computer application skills showed that the computer application skills of computer science majors were significantly higher than those of teacher education majors, which is an outcome evaluation. Based on the outcome evaluation alone, it is easy to overlook the fact that computer science majors take more computer-related courses during their training. It cannot be simply assumed that increasing the number of computer courses taken by teacher-training students will improve their information literacy; it is important to consider that students enrolled in computer science programs are generally more interested in software, electronic technologies, and products, and differences in logical thinking between students in teacher training programs and nonteaching students exist.

2. Current Status of Research

Two attributes, timestamp and geographic location, are the characteristics that distinguish spatiotemporal data from other data. The rapid spread of mobile terminal devices and sensor devices monitor and track the massive behavioral data generated by research subjects on the Internet in real time. Foreign scholars are committed to applying spatiotemporal big data for mining and analysis to reveal regular conclusions [6]. For example, in the field of urban research, it can be used to study the spatial structure of cities and residents' behavioral patterns and so on. At the same time, many scholars are interested in how to represent these new types of data and visualize the results of the analysis [7]. Visualization is an important expression method for big data analysis, which takes advantage of human's cognitive ability for visualized information and organically combines the respective strengths of humans and machines with the help of human-computer interaction analysis methods and interactive technologies, assisting people to gain more intuitive and efficient insight into the information, knowledge, and wisdom behind big data [8]. Since spatiotemporal data carries spatial geographic information, it is often combined with geographic cartography to express, and the key is how to visualize and map the spatial dimension, the temporal dimension, and the corresponding attribute dimension [9]. The spatiotemporal cube visualizes time, space, and events in the form of a 3D coordinate system. A stacked map can also be used to fuse 2D and 3D to expand the space for displaying multidimensional attributes in the space-time cube. However, the display of a 3D coordinate system also has its limitations, especially when the spatiotemporal information objects have more dimensions, so it is often fused with multidimensional data visualization methods to assist the expression [10]. The rapid development and mature application of artificial intelligence technology and big data bring opportunities and challenges to scientific and technological intelligence work, and systematic review and improvement of scientific and technological intelligence service research systems in the data-driven era can provide development ideas for scientific and technological intelligence intelligent service mode [11].

Faced with the trend of intelligent technology and the trend of multisource heterogeneity of massive data, the science and technology intelligence service model faces serious challenges. For example, in the face of massive data resources such as scientific and technical literature and patent literature, the traditional human-driven model cannot realize the semantic extraction of massive multisource heterogeneous data resources, and the characteristics of literature resources such as multilingual and multidomain for accurate extraction of data resources corresponding to scientific and technical intelligence tasks, which requires the development of semantic extraction tools with more enhanced capabilities [12]. The research and application of schema theory in the field of foreign language teaching are dominant, and the research direction is subdivided into the application of schema theory in reading comprehension, listening comprehension, translation, and corpus, but the mainstream of research and application is still limited to its ontology: linguistics; the research of cognitive discipline begins to sprout, which is manifested in the application of schema theory to gain insight into the process and method of language acquisition and the systematic analysis of cognitive patterns, pathways, strategies, and representations in the process of foreign language learning [13]. The research on the reading comprehension process occupies the main position, and the research on cognitive disciplines is still not separated from the field of foreign language teaching; although psychology and philosophy have been involved in this field since the introduction of schema theory, scholars' research in this field is relatively rare and limited in depth.

The purpose of this paper is to construct a data-driven scientific and technological intelligence wisdom service model, improve and enrich the scientific and technological intelligence wisdom service research system, help scientific and technological intelligence service organizations better understand their advantages and defects, recreate the service process according to the scientific and technological intelligence wisdom service model, and develop a wisdom service plan that meets their characteristics. Firstly, the research on data-driven scientific and technological intelligence wisdom service has not been systematically analyzed in terms of its constituent elements and characteristics, and the systematic analysis of the constituent elements and characteristics of the data-driven scientific and technological intelligence wisdom service model on the existing research results is a key part of improving the scientific and technological intelligence wisdom service research system, establishing the correlation between the constituent elements of scientific and technological intelligence wisdom service and systematically cognizing each constituent element.

3. Analysis of Data-Driven Data Visualization and Visual Communication Design Patterns

3.1. Data-Driven Algorithm Design for Data Visualization. The design concept is too much beyond people's basic cognition and aesthetics, which also leads to the failure of design. Such examples are everywhere. Therefore, designers should deeply analyze the ideology of consumers and the psychology of the audience before designing works and should not deal with design concepts that are difficult to achieve. Multidomain heterogeneous data is a kind of big data; it is an important trend and direction that emerged at a certain stage of big data development, which is proposed by researchers or users for expanding data sources, domains, and complex data structures, and big data is an important source and basis for multidomain heterogeneous data generation. Before understanding multidomain heterogeneous data, a brief overview of big data is needed [14]. Compared with the traditional service model, the components of the scientific and technological intelligence service model in the era of big data should reflect the characteristics of intelligent service, and the scientific and technological intelligence service has shifted from the qualitative analysis service model such as expert experience judgment in the past to quantitative analysis based on scientific study big data service model, and the data-driven research paradigm will become the core paradigm of scientific and technological intelligence service. The intelligence service relies more on intelligent devices and technologies, sensing user needs through intelligent data services, using intelligent analysis technologies to obtain intelligence oriented by the concept of integration, and finally using big data on user behavior to push scenario-based services. Science and technology intelligence services are user-demand-oriented, data-driven, and highly knowledge-intensive, and the development and maturity of big data bring opportunities and challenges for intelligence services. The composition of the scientific and technological intelligence analysis process that integrates scientific research big data covers seven dimensions, such as data, users, technology, intelligent intelligence, scientific and technological intelligence workers, and intelligent service platforms and methods. In-depth analysis will be conducted from these seven dimensions, and on this basis, the theoretical and practical basis for the realization of data-driven scientific and technological intelligence services will be discussed, and then the demand sensitivity of scientific and technological intelligence services will be discussed. The theoretical and practical foundations of data-driven STI services will be discussed, and the four main characteristics of STI services, including demand sensitivity, data multisourcing, technical intelligence, and service scenario, will be explained.

Principal component analysis (PCA) is a commonly used method for dimensionality reduction. High-dimensional data is generally very sparse, with most data at the boundaries in a high-dimensional hypercube. This makes analyses such as clustering and outlier analysis, which focus on the distance between points and the degree of aggregation, meaningless. And high-dimensional data also suffer from data redundancy, which reduces the speed of processing data later and takes up storage resources [15]. Therefore, it becomes necessary to represent high-dimensional data with low-dimensional data with as little information loss as possible. PCA style is the simplest method of dimensionality reduction by taking random variables that are originally componential correlated.

$$\begin{aligned} X &= \left(x_1, x_2, \ldots, x_m\right)^2, \\ Y &= \left(y_1, y_2, \ldots, y_m\right)^2. \end{aligned} \tag{1}$$

Data identification is based on the definition of data scope, structure, and attributes, such as for data collection services, after data fusion to refine the available knowledge for data applications, after data identification for collection and organization, and then classification and storage to build the corresponding field of the thematic database, such as industrial technology database, thematic database, intelligence reports database, and research id database. The data will generate new data in the application stage, such as user behavior data (evaluation and feedback data) and so on, which can be used as data identification scope for recirculation. Overall, due to open data release, open-source software, and cloud service innovation, the technical difficulty of online mapping is declining. The construction of scientific and technological intelligence resources has become more prominent in the characteristics of "big data," and intelligent data have become a new orientation for the construction of scientific and technological intelligence resources. In this process, wisdom data service emphasizes semantic interconnection, which essentially improves the standard of data quality and value, and the construction and management of intelligence resources in the field of science and technology continue to innovate and rise, and the construction of various kinds of databases with special characteristics in the field are springing up, so how to reasonably embed wisdom data service, through the fusion of multisource heterogeneous data, correlation, and semantic analysis of data, and then realize the science and technology intelligence service. Intelligent data is the logical starting point of intelligent services; the quality and quantity of data determine the depth and breadth of scientific and technological intelligence intelligent services, as shown in Figure 1.

Small tree-like structures are often considered to be communities, despite their sparse structure. Considering the intrinsic meaning of communities, such a result is counterintuitive and raises the question: is community detection therefore unusable on mobile call graphs? Finally, user behavior big data are used to push scene-based services. Science and technology intelligence services are highly knowledge-intensive services that are user-demand-oriented and data-driven. The results may need to be considered with caution, but as community detection methods always do, this particularity of communities in mobile call graphs seems to be a special rather than a problem, regardless of the network used [16]. Although they may have a single shape, communities can provide important information when useful with external information.

$$\begin{aligned} D &= \frac{1}{m} Y Y_n^T, \\ w_i &= \frac{\lambda_i}{\sum_{j=0}^{k} \lambda_j^2}, \\ X &= \begin{pmatrix} p_{11} - p_1 & p_{12} - p_1 & \cdots & p_{11} - p_1 \\ p_{21} - p_1 & p_{21} - p_1 & \cdots & p_{21} - p_1 \\ p_{31} - p_1 & p_{31} - p_1 & \cdots & \cdots \\ p_{41} - p_1 & p_{41} - p_1 & \cdots & p_{41} - p_1 \end{pmatrix}. \end{aligned} \tag{2}$$

The human brain can process visual features such as curvature, color, and so on and will process this information much faster than it can process symbolic information. For example, an observer can easily find a blue dot in a mass of red dots mixed with a blue dot or even spot the blue dot without being prompted. Information visualization takes advantage of the developed nature of the human perceptual system to be able to process large amounts of data quickly. Good visualization can convey information more efficiently and directly, which is an advantage of the method used in this study. Visual analytics is a combination of automatic computer analysis capabilities and human cognition of visual graphics, based on which Lei Ren et al. analyze in detail the cognitive theory, information visualization theory and human-computer interaction, and user interface theory that support the analysis process and discuss information visualization techniques for mainstream applications of big data and human-computer interaction techniques that support visual analytics. They use pixels of different colors to represent different data attributes. The position and order of the pixels can be used to represent semantic information such as level of interest or item similarity, and this visualization design can be used well to represent large data sets. Many visualizations in this category are based on hierarchical aggregation techniques, and often such visualizations distinguish information details for scalability, so there is little visual clutter after the data is visualized [17]. There has been much excellent research in the field of visualization based on visualization design. A proper spiral layout design can make trends in periodic data more visible when the right period is chosen. This is a very much used method to reveal periodic patterns in temporal data along a spiral timeline by parameterizing the visual design.

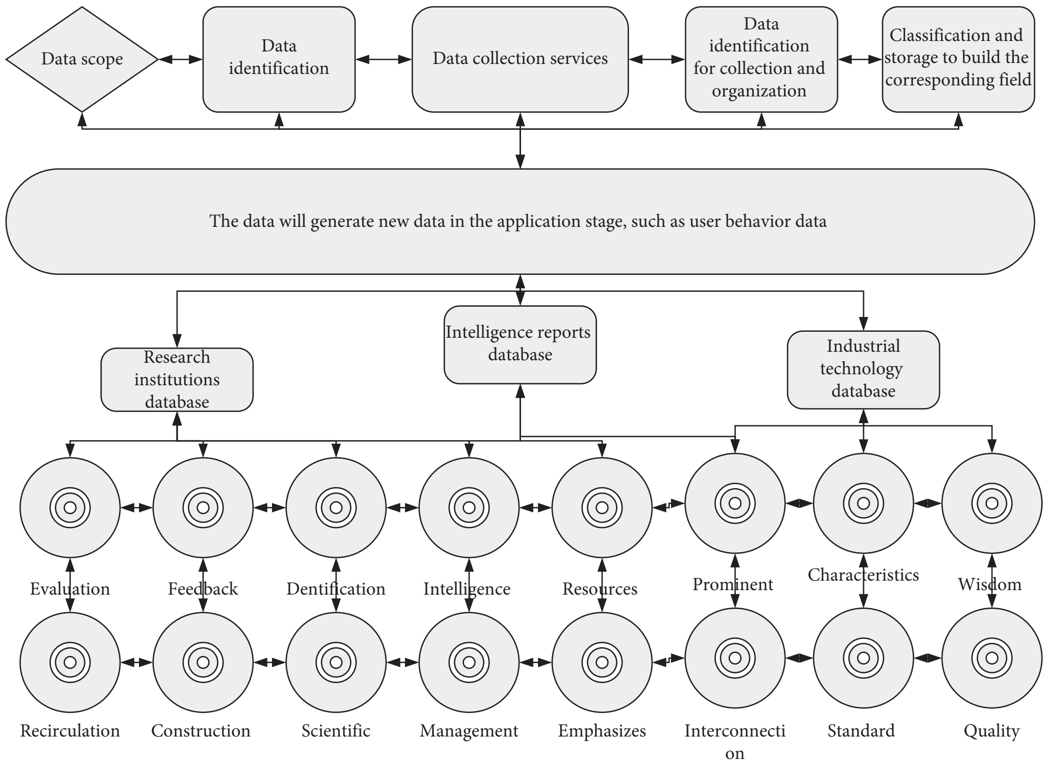

Figure 1: Data-driven framework.

$$p_{AB} = \frac{Cov(a, b)}{\chi_a \lambda_B},$$
$$A = \left[\sqrt{\lambda_1 \eta_1}, \sqrt{\lambda_2 \eta_2}, \ldots, \sqrt{\lambda_n \eta_n} \right]^{1/2}. \tag{3}$$

As an example of a diagrammatic reaction force, forces occur in pairs, and the action involves the active encounter of equally powerful physical or metaphorical opposing forces, which is the reaction force. The effects of reaction forces are more common in life, such as slapping a basketball or loosening a compressed spring. In design, proper use of reaction forces can receive good results, such as the proportional relationship between the length of time and the strength of pressing the cue in a billiards game; the game Jump a Jump also uses the same principle; pinball games and Angry Birds are typical applications of reaction forces in design, as shown in Figure 2.

Spatial schemas cover a variety of subgraphs that are closely integrated into human activities such as orientation and space and have a wide range of cuts in design and multidomain heterogeneous data visualization. User behavior data can be recirculated as the data recognition range. The construction of scientific and technological information resources has highlighted the characteristics of "big data," and smart data have become a new direction for the construction of scientific and technological information resources. Their prominent role is not only in the basic composition but also in close cooperation with Gestalt-based design methods, which play an important and prominent role in the visual representation and interactive operation of multidomain heterogeneous data. The original purpose of data visualization is to map a wide variety of multisource heterogeneous data sets into geometric elements through algorithmic design and then output graphical images to show the structure and insight into the laws in an intuitive, clear, and concise manner. Data is an asset, and data visualization is an important tool to revitalize this asset. The set graphical style for data sets of the same kind of homogeneous merging, link graphical style for related data sets of relationship mapping, and part-whole graphical style for complex data sets of the point surface are the outstanding embodiment of simplification. Appropriate use of these composite schemas in the design of visual representations can provide intuitive insight into patterns, facilitate knowledge acquisition, and maximize the value of information.

3.2. Visual Communication Design Model Design. After the data has been cleaned, there are still problems such as sparse information density, so the information contained in the data needs to be mined. Operators want to understand the communication patterns of user groups in the local network, including the distribution of local users under each characteristic, which characteristics of users should be the focus of attention; how to identify ordinary and prominent users through objective methods; and other information. This requires us to find objective and effective methods to be able to accurately mine user group information [18]. Traditional analysis methods are designed using line graphs and histograms, but in the analysis process, only two to three

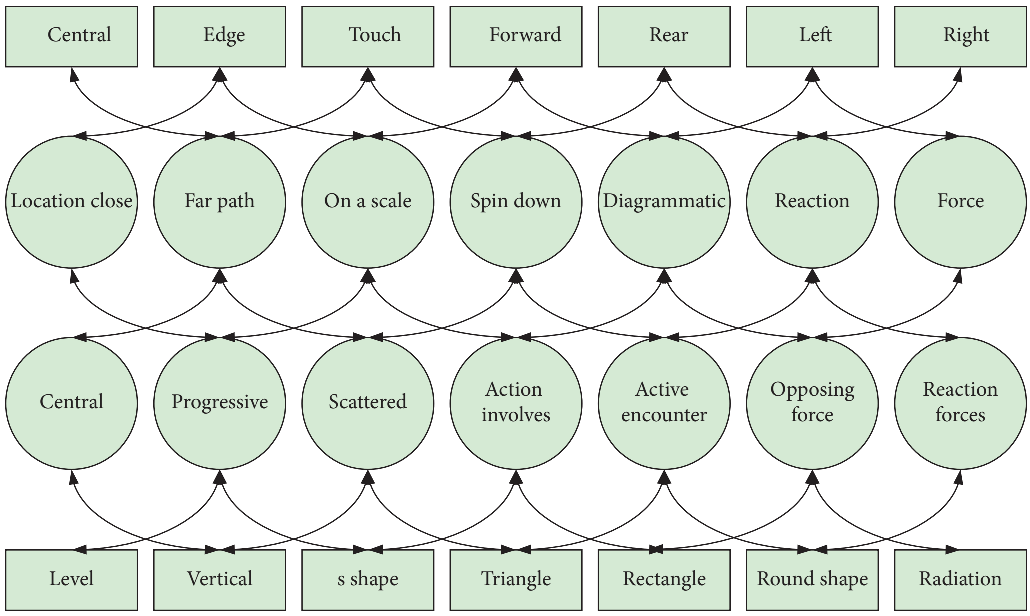

Figure 2: Data visualization steps.

dimensions of data can be selected for analysis, which greatly limits the depth of the information mined, making the information obtained in the analysis incomplete, and if a dimensionality reduction algorithm is adopted, the information displayed is also incomplete if the user is only interested in certain user characteristics. The user data density of call recording data is sparse, and there is the problem of incomplete analysis samples if only some of them are filtered for study. In terms of layout, the simplest way to represent a user is to take a point representation, but if the number of users is large, such as a shopping site with up to hundreds of millions of users, choosing to depict users with points would show points that are too dense for the display screen area to accommodate, as well as problems of visual confusion and occlusion coverage. Therefore, in this study, there is a need to abstract sparse user data records into machine-recognizable user features, with the aim of mining effective data information, improving the efficiency of the system in processing and drawing data information and designing clear and beautiful visualizations based on data analysis results to effectively communicate data information to users.

Due to the space limitation of the Cartesian product coordinate system, a few features are selected in this paper to analyze the distribution of users. The coordinates of intranet contacts and extranet contacts of users in the features are first selected for comparison, as shown in Figure 3. The horizontal coordinate is the number of intranet contacts, and by looking at the figure, we can roughly see that the order of magnitude of users' extranet contacts is larger than the order of magnitude of intranet contacts, which means that generally, users have more extranet contacts than intranet contacts. But from the graph also that shows the shortcomings of this depiction, most of the users still have some similarities, and the communication behavior pattern also has some similarities; at the same time, the data volume of this experiment is large; there are more data points; the situation of obscuring and covering is more serious; and the information cannot be displayed clearly and intuitively.

In this paper, we want to obtain specific feature data for each point, and we want the data points to be in such a way that they cannot be covered and obscured, and the data points are visible [19]. To this end, a checkerboard layout was adopted to plot each coordinate point, which was able to demonstrate the needs of this analysis task and confirmed the above observations clearly and unambiguously. After this, the limitations of the layout were still found, taking this layout, depicting the limited distance of the axes, and not being able to observe other users who are not within the coordinates. If the plotting is done by zooming or sliding to select the coordinates, the user needs to slide the coordinates several times to observe all the data points, which means that the user cannot view all the information in a short time, which is not compatible with the theory of visualization to convey information quickly. Visual analysis is a combination of computer automatic analysis capabilities and human cognition of visual graphics. On this basis, Ren Lei and others analyzed in detail the cognitive theory, information visualization theory, and human-computer interaction and user interface theory that support the analysis process. And information visualization technology for mainstream big data applications and human-computer interaction technology that supports visual analysis is also discussed.

Inverse thinking, which can also be called divergent thinking, is what people take for granted in the opposing mode of thinking expression so that the design state will give people a new visual impact. For example, in the process of visual expression, the same theme using cis-thinking is difficult to stand out in many design works; more will make the audience produce visual fatigue. Instead, reverse thinking will give the audience a sense of visual impact at first sight. In reverse thinking, it is necessary to consider the universality of simple elements in

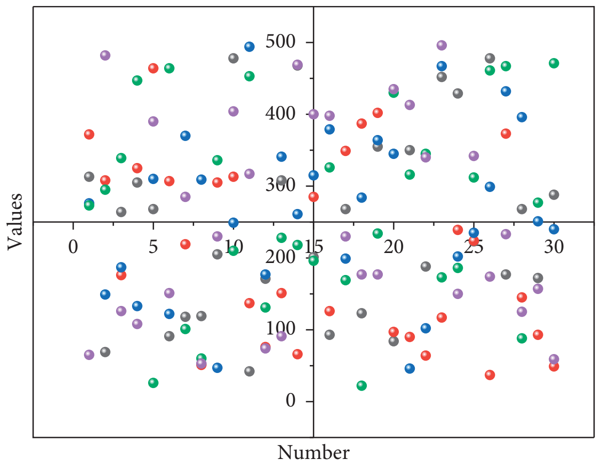

Figure 3: Distribution of intranet contacts and extranet contacts.

the audience's common design work, such as color changes, opposite sizes, or the choice of opposites, which can be the point of view of transformation. Using the design concept of guidance and challenge to observe the audience thinking blind, breaking the conservative design thinking concept, bold use of new elements and new composition methods, the audience often agrees with things in reverse thinking but has a critical point of view, which is also a breakthrough for the traditional way. This is where the designer needs to notice the novelty in reverse thinking, establish a new design concept, and focus on the sense of innovation, as shown in Figure 4.

The results of multisource data fusion are used to reveal different dimensions of an event or activity, showing facts or patterns side-by-side, where the same facts or patterns may be hidden in different forms in the data network and where the same form of data exists to show one or more dimensions of the same facts or patterns. If the dimensionality reduction algorithm is adopted, if the user is only interested in certain user characteristics, the displayed information is also incomplete. Multisource data fusion is the basis of computational intelligence and is the embodiment of quantification, automation, and fusion thinking [20]. The process of conducting decision research decomposes the task into different subtasks, constructs a multisource data fusion model for the data sources of the subtasks, and is oriented to the task context, and the process of data collection, processing, and analysis should be oriented to the context in which the subtasks are located, covering all the data sources required for the task. The development of data-driven thinking is gradually moving towards the development path of synthesis, multisource, and refinement, with data focusing more on the whole rather than traditional sampling data, more on precision rather than on efficiency, and better reflecting cause-and-effect relationships, overturning the previous model of intelligence task interpretation. Multisource data fusion places more emphasis on the complementarity between data, the ability to corroborate each other, and more emphasis on large and broad. At the level of data fusion algorithms, targeted data fusion algorithms are becoming more sophisticated in various fields.

4. Analysis of Results

4.1. Data Visualization Results. An important challenge in visualizing multidomain heterogeneous data is that the designer must control the amount of information in the visualization map; too much or too little information can cause some distress to the user in receiving the information. Visualizing too little data can be a waste of resources, typically data that contains only two opposing attribute values, such as the number of present versus absent, gender comparison, pass versus fail ratio, and other data that sum to 100% and can be derived from one attribute to the other, for which other more intuitive ways of displaying the data are available and have no visual value. In contrast to this is another situation where designers want to express too much information, believing that a visualization containing too much information not only increases the complexity of the visualization but also makes the visual schema confusing and difficult to interpret, making it difficult for end users to understand, obscuring necessary information, and causing problems for users to understand the data. The combination of attribute and composite schemas can alleviate this problem to a certain extent for designers. One way is to provide users with the operation of filtering and filtering data according to the size, density, and importance of the data so that users can select the data to be displayed in the current scene. Another way is to combine and divide the data in an orderly manner as proposed above, through multiple views or multiple screens and cross-screen to split the display according to user needs and relevance.

In multidomain heterogeneous data visualization design, color is second only to graphical layout in terms of expressiveness. However, in some cases, color has a communication effect that graphic layouts do not. The effect of color on human emotions in data visualization is not available in layout. The proper use of color can help users understand data structure more intuitively, detect data anomalies, focus their attention, and enhance their understanding of abstract data. If the graphic layout reflects the control of the designer's reason, then the color in visualization puts a warm coat on the cold data, which brings spiritual comfort to the viewer, and the impact of color on the user focuses on emotional experience. Color in current design practice is one of the more extreme elements of data visualization, either ignored or abused, as shown in Figure 5.

Users of data visualization systems also indirectly assume the role of evaluation, where the evaluators are mainly users who test and evaluate visual graphics and visualization systems. Users cannot view all the information in a short period of time, which is inconsistent with the visual theory of rapid information transmission. Evaluation is important to find out the shortcomings of the visualization system, improve the user experience of the system, and evaluate the advantages and disadvantages of technical solutions. Evaluators generally consist of two types of users: expert users and general users. Expert users are professional users who meet certain conditions of the visualization system (industry experts, technical experts, etc.). These users have a thorough understanding of the data or the goals to be achieved, have a

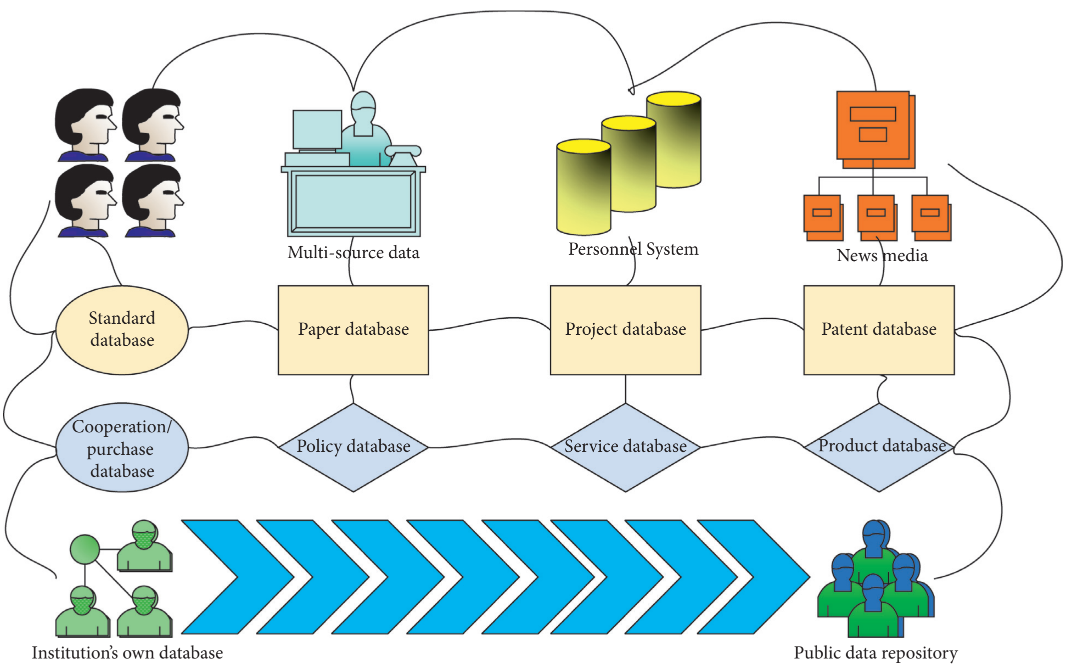

Figure 4: Visual communication design model.

clear judgment of the usability and ease of use of the system, and can provide quality suggestions for the iteration of the visualization system. General users generally evaluate the public-oriented visualization system, which has a greater uncertainty of users, and the main purpose of testing is to improve the compatibility, friendliness, and ease of use of the system for users, which is generally done through task execution analysis, eye-movement data analysis, or subjective evaluation, as shown in Figure 6.

At the same time, the difficulty of mining user needs, especially deep user needs, increased by the characteristics of partial expression, false expression, and abandonment of expression for various reasons. For this reason, the article tries to mine the deepest emotional needs of users from the perspective of data visualization. Emotional demand is the state and direct expression of human nature, the deepest demand of users, and a cultural trait based on the original rhythm of life and higher than life in a narrow sense. Whether the emotional demand of users can be accurately mined and fully satisfied is one of the important criteria to measure whether the multidomain heterogeneous data visualization system has an innovative spirit and humanistic care. Based on the effective mining of information about users' inner emotions in multidomain heterogeneous data visualization, we analyze them in depth and obtain insights about users' emotional differences and inner needs.

The extraction of imagery patterns requires a high degree of accuracy in user wording. In industry-oriented multidomain heterogeneous data visualization design, users are mainly professional and semiprofessional, and the extraction of imagery patterns in such visualization systems is based on structured interviews, which facilitate designers to directly extract subpatterns of high relevance. Data with a sum of 100% can be derived from one attribute to another attribute value. Such data can be displayed in other more intuitive ways without visual value. The public-oriented data visualization platform is based on scene observation, supplemented by semistructured interviews, which can extract relevant subpatterns efficiently and accurately.

4.2. Visual Communication Design Results. After understanding the new performance of visual communication in the new media environment, while focusing on dynamic performance and interactive performance, it is also necessary to have innovative performance on the basis. Inheriting the growth of traditional media visual communication performance based on the creation of new forms of expression, to improve the expansion of visual advertising design, is also the design of the place's connotation.

Through the dynamic form of visual expression that enables the audience more likely to accept the products marketed, the new media environment and the traditional media environment development of visual design development of different performance is also evolving, from the previous simple and easy-to-understand direct form of expression into a subtle performance; because the quality of today's nationals is continuing to grow, the level of thirst for knowledge is increasing day by day, making it simpler to float about the things brought in. This is a great breakthrough for the design form of advertising to reflect the change. In design, we can use simple elements around us to represent some spiritual feelings that want to express complex psychological states so that the scene can create emotions and resonate with visual psychology and other states. The visual symbolization of the product increasingly becomes the representative direction to attract the eyes of consumers, for the product of successful packaging design or advertising design is indeed the consumer impulse to

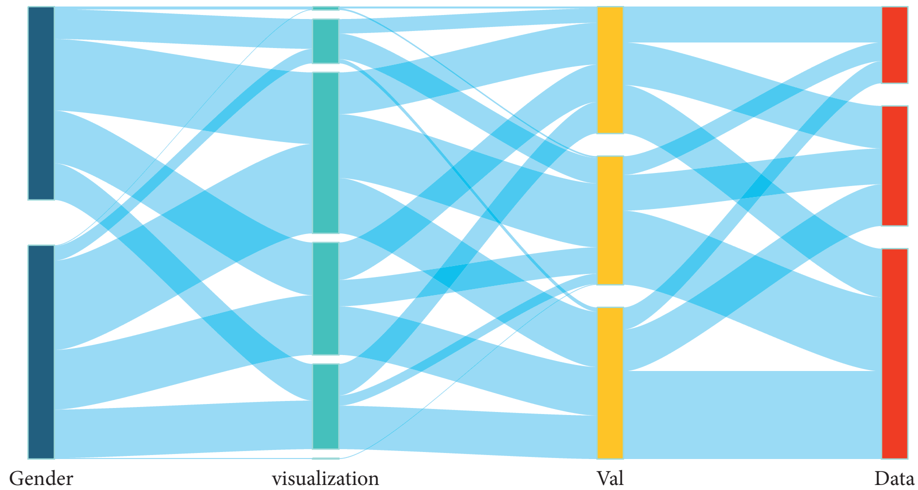

Figure 5: Data visualization assessment.

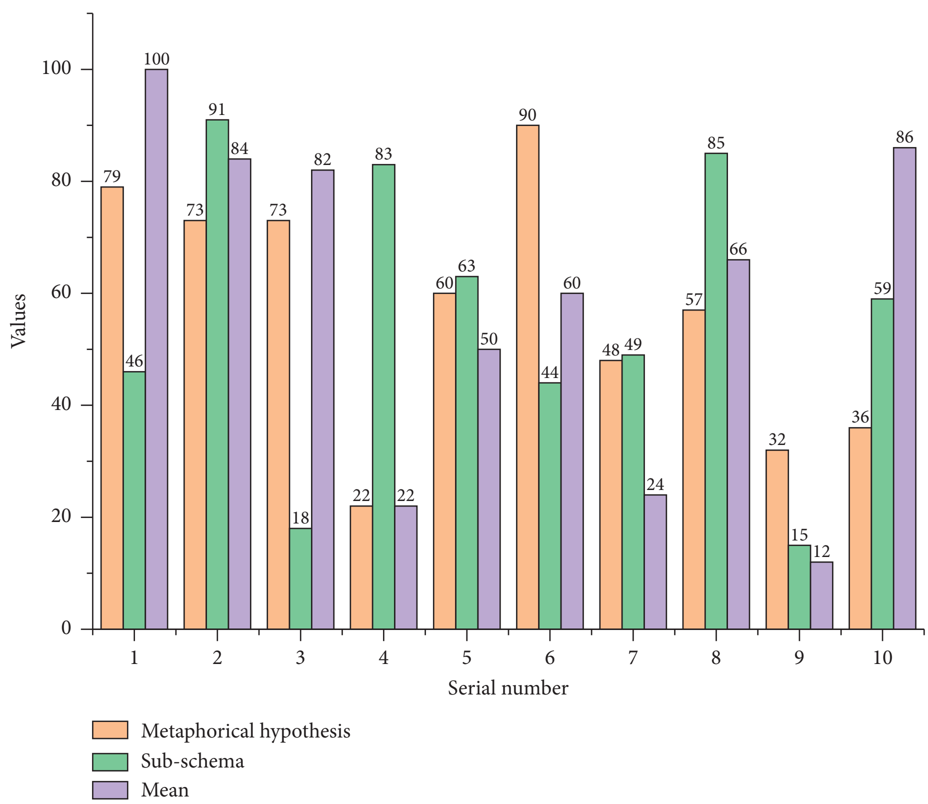

Figure 6: Validity measures.

produce consumer ideas. People must be visual product expressions of whether the consumer view resonates with the psychology of the consumer in order to grasp the product of the development of emotional consumption, as depicted in Figure 7.

If the product's external image is split, such as the product's shape, material, and color, the buyers can get an instinctive sensation able to make high-quality ideas for the visualization system's iteration. Ordinary users generally conduct evaluations on public-facing visualization systems. Users of this type of data visualization system have greater uncertainty. The main purpose of the test is to improve the compatibility of the system with users. The second is the behavior level for the experience of consumer behavior; seeing the product's first sense is also the psychological state whether there is a sense of pleasure. The third is about the experience of the consumer's emotional state, based on whether the consumer's inner state resonates with the product to promote the desire to buy the product. The fourth is about the consumer's associated

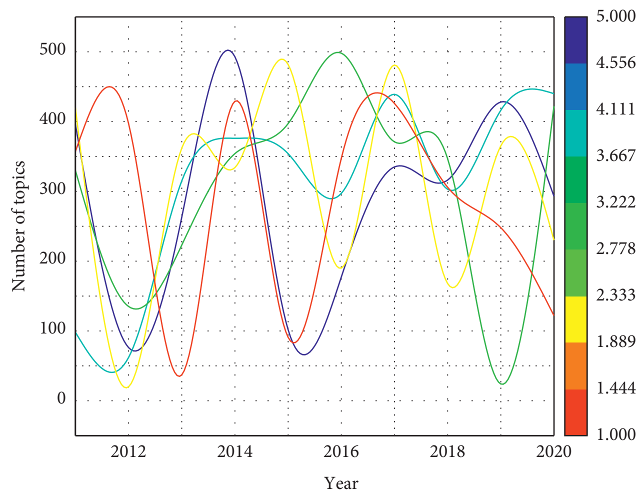

Figure 7: Structural drawing visualization layout design results.

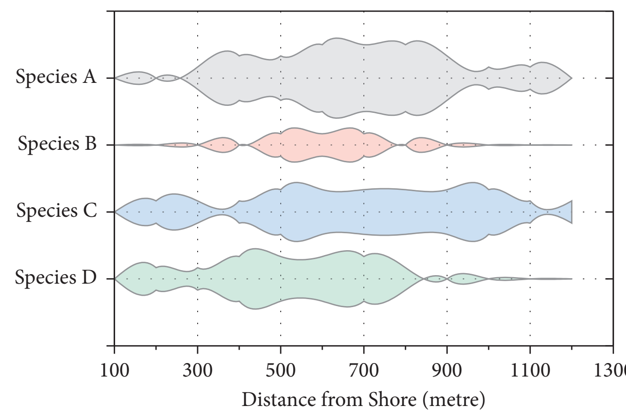

Figure 8: Visual communication design results.

experience, which also needs to be associated with the product's after-sales service, whether the consumer can feel at ease to buy the product after the experience is also key. Therefore, by analyzing the characteristics of consumer experience, we can learn that the first sensory experience mainly corresponds to the consumer's consumption state whether there is a sense of impulse to consume, the second experience corresponds to the emotional analysis of the consumer's purchase state and whether there is a positive level of aspects, the third experience is through the consumer's experience whether there is a psychological level and the establishment of emotions and whether the product has produced consumer trust, and the fourth experience is whether the consumer builds a cognition of the brand culture after understanding the product and whether he or she has the will to establish a long-term relationship to cultivate consumer consumption awareness, as shown in Figure 8.

Visual communication performance is to serve the audience, but there is still a very clear division of the audience; for different levels of consumption level, habitual acceptance of the media is clear, so more attention is paid to the commercial value of visual communication performance. The development of visual communication relies on digital technology in the form of expression, and the integration of design expression with the benefits of business is also an inevitable development trend. The gradual commercialization of visual communication performance has also become aesthetic and humanized. In the visual communication and the new media, the environment reflects the value of reciprocity; the performance form is closer to the market and integration in the economic development today. Because of the constant closeness to market requirements, visual communication performance has also changed qualitatively. For the audience, an examination of people's visual psychological state for visual development and the economic market can promote a more perfect integration.

5. Conclusion

In the process of designing multidomain heterogeneous data visual systems, imagery schema theory can inspire designers' creativity, improve design efficiency, and help designers find innovative design solutions, which can improve design efficiency and bring novel user interface designs to design works compared to other design approaches. The integration of visual communication in the new media environment has also led to the emergence of new visual models. For example, motion graphic design can provide the audience with a more intuitive understanding of the meaning of the expression. Secondly, interaction design allows the audience to interact with the visual work. The second experience is the emotional analysis corresponding to the consumer's purchase state and whether it has a positive level. The third experience is whether a psychological level and emotional establishment are generated after the consumer's experience. The design also pays more attention to the feedback link of the audience, so the direction of the design pays more attention to the "human-centered" design concept. The development of visual communication is promoted with the assistance of new media and Internet technology, and the concept of multisensory acceptance is adopted in the expression of design transformation forms. In today's era of rapid economic development, the conversion of visual communication expressions is increasingly developed in the direction of commercialization. This paper analyzes the consumer psychology, consumption patterns, and aesthetic trends of consumers so that we can accurately integrate the consumer market better in the form of design conversion.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author does not have any conflicts of interest.

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Research Article

Analysis of the Practice Path of the Flipped Classroom Model Assisted by Big Data in English Teaching

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This paper makes a detailed analysis of the integrated mining algorithm, analyzes the characteristics of curriculum big data, and analyzes the existing problems of the current association rule mining algorithm, as well as the defects and deficiencies when applied to the curriculum data. Aiming at the problem of mining the entire data set by the mining algorithm, this topic proposes the idea of using the K-means algorithm for clustering processing and uses the Ball-tree structure on the basis of the original K-means algorithm to improve the efficiency of the algorithm. The data set is separated into several clusters of an appropriate number. In the flipped classroom, the basic knowledge is put before the class for learning, and the further deepening and practical application of language knowledge is completed in the class. Teachers can give timely guidance when encountering unsolvable difficulties so that students' learning can be more effective. This new teaching model not only strengthens students' confidence in learning and increases their interest in learning, but also increases the opportunities for students to interact with teachers and classmates in the classroom, allowing them to construct the meaning of knowledge in the fun of interactive communication. The classroom has become relaxed, lively, and attractive, and students' sense of autonomy, self-learning ability, and collaborative inquiry ability have also been unknowingly improved. Among the main factors, the willingness to flip, emotional state, leadership role, and online learning input have a significant positive impact on collaborative learning performance, and the sense of competition has a partial negative impact on collaborative learning performance, of which positively affecting individual knowledge mastery. Among the nonmain factors, the degree of difficulty of the course, teacher-student interaction, teacher motivation, and evaluation mechanism have a significant positive impact on collaborative learning performance. Classroom assistive technology has a partial negative impact on collaborative learning performance. From the perspective of group performance, group-level performance considerations such as the quality of group conversations and the degree of group knowledge sharing in collaborative learning performance are more affected by nonsubject factors.

1. Introduction

With the integration and development of computer and communication technology, network infrastructure is becoming more and more perfect, equipment terminals are rich and diverse, and network applications are more extensive; the Internet has increasingly penetrated into people's social life, opening a new era [1]. Due to the characteristics of the Internet and computer digital processing, all behaviors of people in the process of popularizing the use of the Internet are transformed into data information [2]. These data and information are collected and stored into digital records through terminals, networks, and servers, forming a big data environment in which everything is digital and everything can be quantified. The real material world in the Internet age is transformed into the real data world. The comprehensive campus network infrastructure, extensive application of information systems, and the popular use of new technologies, new equipment, and new applications by teachers and students have formed a mature campus big data environment with good conditions for big data applications [3]. In the context of the era of big data, flipped classrooms were born and developed rapidly as a new teaching model. In recent years, the research and application of this model have been very hot in foreign countries [4]. Many domestic universities have applied this model to the teaching of different subjects and have gained successful experience [5]. The characteristic of flipped classroom is that it reverses the sequence of learning knowledge in class and completing homework after class in traditional teaching [6].

In traditional teaching, students acquire new knowledge in the classroom and consolidate knowledge by completing homework after class, while students in flipped classrooms acquire knowledge by watching videos made by the teacher before class and then resolve questions with teachers and classmates in class [2]. The introduction of flipped classrooms into college teaching will help promote the innovation and exploration of college teaching models and promote the transformation of college teaching models to informatization, high efficiency, individualization, and humanism. Related theories provide new ideas and theoretical references for the future application of flipped classrooms in college classroom teaching [7]. Flipped classroom teaching can fully stimulate students' potential for independent and active learning. Before the class, students can learn independently by watching microvideos or other learning materials anytime and anywhere, and control the pace of learning by themselves. In this process, students will gradually cultivate their independent learning ability and sense of responsibility for learning. In the classroom, there are learning activities such as problem discussion, group cooperation, and results display. In this process, students' interpersonal communication and cooperation ability, high-order thinking ability and independent learning ability are gradually cultivated [8]. Through case studies on the use of flipped classrooms in colleges and universities, it analyzes and summarizes the teaching ideas, teaching strategies, and teaching principles implemented by flipped classrooms in colleges and universities. The construction of a classroom teaching environment that respects the individuality of students in teaching provides a reference for operation.

According to the existing association rule mining algorithm, its advantages and disadvantages are analyzed and ideas for improvement are put forward. We analyze the characteristics of the curriculum data set, and we analyze the reasons for the inapplicability of the current algorithm, propose an integrated idea of combining multiple algorithms, analyze its advantages, and verify the experiment according to the above idea as well as realize the proposed integrated algorithm. We compare the efficiency gap with the previous algorithm. In the flipped classroom, students start collaborative learning in the classroom based on the knowledge and background of the relevant courses. This is also a point that is special in traditional classrooms. The source of student knowledge and experience is the flipped teachers on the online learning platform of "Chinese College Students MOOC" online learning platform. The learning tasks and learning resources released by teachers in Yu Classroom before class, the weekly course online test, and the knowledge review link in the classroom all emphasize the importance of learners' online self-study before class. At the same time, differences in the length and frequency of learners watching videos and completing exercises, as well as classroom test scores, also indicate differences in students' online learning input. Students with a higher level of input are aware of the knowledge reserves and strategies required to complete the task, and it is relatively easy to make tacit knowledge explicit in each link of collaborative learning. Therefore, the degree of learner's online learning input has a significant positive effect on both the individual learning performance of collaborative learning performance or the group learning performance.

2. Related Work

Flipped classrooms in Western countries (such as the United States, Australia, and the United Kingdom) have begun to be widely used in graduate and undergraduate teaching, and the teaching subjects and research fields involved include medical care, nursing, biochemistry, and materials science [9]. Their research on flipped classroom teaching methods is no longer limited to theoretical research and more turns to teaching practice. They have even used flipped classrooms to devote themselves to applications in other fields, such as using flipped classrooms to develop students' learning skills and self-reflection abilities.

The American education consulting company Class Window released a survey report that revealed the application value of flipped classrooms [10]. A total of 450 teachers participated in the survey. Among them, 88% of teachers said that their satisfaction had improved, 46% of teachers reported a significant improvement, and 99% of teachers said that they will continue to use flipped classroom teaching next year. Columbia University conducted a survey of 203 students from the United States [11]. The survey found that 80% of the students said that they have more frequent and active interactions with teachers and peers in flipped classrooms, and there are more course materials they need to read in flipped classrooms. There are also more opportunities to learn and practice according to their own time, and more opportunities to demonstrate learning results. Students are more willing to regard learning as an active and active process. Speak Up Survey surveyed 43,000 K-12 students, parents, and administrators [12]. Through a survey of managers, it was found that 25% of managers indicated that flipped classrooms are the most important change in teaching, which surpassed educational games. It can be seen that the flipped classroom teaching method has generally been recognized by foreign students, parents, and managers and has high feasibility.

Domestic scholars mainly conduct research on the teaching strategy, teaching process, and subject and object of the flipped classroom [13]. Based on the flipped classroom under the conditions of informatization, the teaching strategy is more flexible, the teaching process focuses on problem-solving, and students have more decision-making power [14]. Although the research on flipped classroom content is relatively broad, the research depth is not enough. Furthermore, a mature theory has not yet been formed, and many schools, especially basic education schools, often just try to flip classroom teaching [15]. It is difficult to do in-depth research only by completing a few demonstration classes on a certain topic. By trying several flipped classroom teachings with enthusiasm, the experience gained may not withstand the test of practice. Adhering to normalized flipped classroom teaching will greatly promote the research of flipped classroom teaching mode, and the practical experience gained is also worth learning. In the era of big data, the use of big data thinking to guide and optimize normalized flipped classroom teaching makes classroom teaching a new look. A middle school in Chengdu insists on normalized flipped classroom teaching, and it collects student learning process data, uses this data to guide and optimize flipped classroom teaching, and has gained some experience [16].

The University of Wisconsin-Madison used eTeach software to synthesize lecture videos and courseware simultaneously and successfully carried out the flipped classroom teaching reform [17]. Multimedia teaching technology creates necessary conditions for flipped learning and emphasizes the technical characteristics of flipped teaching mode [18–20]. In a teaching practice, related scholars helped students who were absent from the classroom make up lessons by recording videos of applying PPT in classroom teaching and then uploading them to the Internet for students to download and learn by themselves [21–23]. Through this teaching attempt, they found that the students' understanding and internalization of the video requires the guidance and help of the teacher, so they reversed the order of the classroom. Through this teaching experiment, the idea of flipped classroom teaching has been further disseminated in American primary and secondary schools [24].

3. Method

3.1. Characteristic Analysis of Course Data. English flipped classroom teaching has provided a good path and opportunity for our educational scientific research work. It has constituted a cross-ethnic, cross-cultural, cross-professional, and cross-social communication platform. By studying these educational data, we can discover new information hidden in the data. The English cloud education platform network assisted by big data is shown in Figure 1.

Curriculum big data, as a relatively common type of data in education big data, has the following characteristics:

(1) Wide range of data sources: the big data of the course has a wide range of sources and a large scale. English flipped classroom teaching has many advantages, such as unique convenience and high efficiency. More and more students choose English flipped classroom teaching to learn and supplement their own knowledge reserves. There are also more and more educators and schools starting to use the English flipped classroom teaching platform for online teaching. More and more managers begin to use the English flipped classroom teaching management platform for online data management. Therefore, the English flipped classroom teaching platform has a large amount of student selection data, school curriculum data, educator teaching data, and a large number of comment data, etc. The source of curriculum big data is very wide, and it is no longer limited to schools or education bureaus.

(2) Higher potential value: curriculum big data does not only come from students, so the analysis and application of curriculum big data is no longer limited to students who need to learn but can be expanded to more lecturers and education managers. Therefore, curriculum big data has a higher potential value.

(3) More relevant: there may be certain relationships between data, and the values of certain variables may affect each other, but this correlation is generally weak and usually not causal. Compared with other types of education data, curriculum big data has greater opportunities for each feature variable to influence each other and stronger correlation. For example, people who choose to learn front-end technology may be more willing to learn front-end-related technology; students who learn testing techniques are more willing to learn such as automated testing, black-and-white box testing courses, and so on.

(4) Larger amount of data: generally speaking, curriculum big data has the characteristics of large quantity and high dimensionality. Some courses will have multiple characteristics, and some courses will also belong to multiple course categories at the same time. For example, in the course selection data of students, each course of selection data will have its own category. These categories are diverse, and each student's course selection tendency is also different.

3.2. Problems in Association Rule Mining Algorithms and Improvement Ideas. Association rule mining algorithm is a mining algorithm that discovers frequent itemsets. It is an important subject in data mining. Its main function is to find hidden relationships between specific data sets and find valuable information from it. The process of association rule mining is roughly divided into two stages. The first part requires finding frequent itemsets in the original data set. The second part digs out association rules from these frequent itemsets through pruning and sorting.

Common association rule mining algorithms are mainly based on the corresponding association rules for the entire data set to mine. When the data set is very large, it will often produce massive amounts of redundant data and similar association rule mining results, which will also cause the final mining results of the association mining algorithm to be too accurate. For example, the Apriori algorithm finds frequent itemsets by frequently accessing the database. When faced with massive data sets, this frequent access to the database operation method will reduce the efficiency of the algorithm as the data set expands.

Although the FP-growth algorithm avoids a large number of database accesses by establishing the FP-tree, a large amount of data will also cause the FP-tree to be too

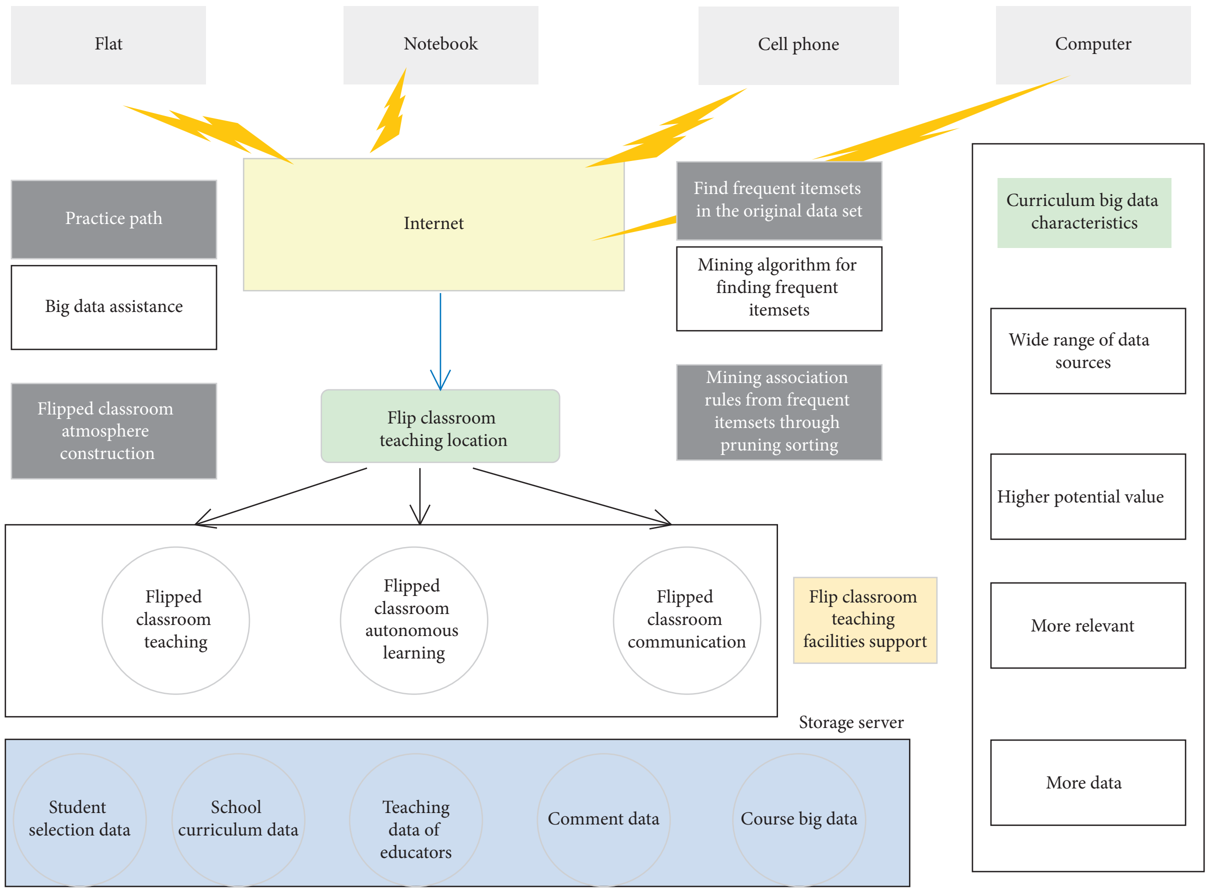


Figure 1: English cloud education platform network assisted by big data.

large. Therefore, this will greatly affect the overall efficiency of the algorithm and the accuracy of the mining results, which cannot be well adapted to the characteristics of curriculum big data.

Top-K is an association rule mining algorithm designed by Fournier-Viger. Compared with the traditional association rule mining algorithm, the advantage of this algorithm is that the user can specify the number of rules to be generated K, avoid generating too many rules, so the efficiency is higher than the traditional association rule mining algorithm.

In this topic, improvements are made on the basis of Top-K association rule mining algorithm, and correlation coefficients are added on the basis of Top-K algorithm to improve the accuracy of the algorithm and further improve the efficiency of the algorithm. In view of the large number of data sets and high-feature dimensions, the K-means algorithm is improved to adapt to the situation of high-dimensional data. The K-means algorithm can refine the data set into multiple small data sets, and each data set represents a category. With the collection of the same feature vector, the accuracy and efficiency of the mining results are improved through the idea of classification and mining. However, the traditional K-means algorithm is not very adaptable to high-dimensional data, and the KNN algorithm uses KD-tree and Ball-tree to optimize the processing methods of high-dimensional data and compares the similarities between the K-means algorithm and the KNN algorithm. Therefore, this topic uses the Ball-tree structure to optimize.

3.3. Analysis and Improvement of K-Means Algorithm. Cluster analysis is to group according to the information involved in the data contained in the description of the objects or the relationship between them. There are many kinds of clustering algorithms, but not all algorithms are suitable for this experiment. Considering the efficiency of the algorithm, we prefer to choose the clustering algorithm with high efficiency. One of the biggest advantages of clustering methods based on definition partitions is their fast convergence rate and convergence speed, and for some large data sets, they are simple and efficient, with low time and complexity. The K-means algorithm is a typical clustering algorithm based on the distance between targets. The distance between targets is used as an evaluation index for the degree of similarity between targets. That is, if the distance between two targets is closer, the possibility of them being the same cluster is greater.

First, we need to determine the size n of a known selected sample data set, and the feature dimension of each selected sample data set is m, recorded as

$$\xi = \left[X_{1i} \quad X_{2i} \quad \cdots \quad X_{mi} \right], \quad i = 0, 1, 2, \ldots, n-1. \tag{1}$$

Then, we need to set the required number of clusters K. And we need to randomly select the final cluster center point that is the same as the set number of clusters k in a data set.

$$\zeta = \left[\zeta_{1j} \ \ \zeta_{2j} \ \ \dots \ \ \zeta_{mj} \right], \quad j = 0, 1, 2, \dots, k-1. \tag{2}$$

For each point in the data set, we calculate the Euclidean distance between each centroid and each point. According to the criterion of the closest distance, they are divided into the corresponding classes closest to the cluster center (most similar), calculated as follows:

$$\xi(i, j) = \sqrt{\left(\zeta_{1j} - x_{1i}\right)^2 + \left(\zeta_{2j} - x_{2i}\right)^2 + \dots + \left(\zeta_{mj} - x_{mi}\right)^2}. \tag{3}$$

After putting all the data together, there will be K sets. If the distance between the newly calculated centroid and the original centroid is much smaller than the expected threshold, then we can be sure that the sample clustering does not reach the expected classification, and the algorithm may be terminated. If the newly appearing center of mass differs greatly from the original center of mass, it will change, and the above steps must be repeated again.

It can be clearly seen that the K-means algorithm achieves the goal of sample clustering through multiple iterative calculations. In each iteration of the calculation process, it is necessary to reset and calculate the center point of each sample cluster, and replace the previous sample center point, which is used as the sample center point for the next iteration. The final sample center point can be considered as the final cluster center.

The K value of the K-means algorithm affects the result of clustering. The original K-means algorithm uses a method of randomly selecting K values. This method is extremely unstable and cannot get stable and good results. The larger the K value of the cluster, the more detailed analysis and division of the data. When the K value is less than the number of clusters, since the increase in the K value will greatly increase the clustering degree of each cluster, the SSE (sum of square error) will also decrease. When the K value is greater than the number of clusters, increasing the value of K will increase the degree of polymerization, so the decline of SSE will also decrease sharply and then gradually flatten out. In other words, the K value corresponding to the inflection point of the relationship graph between SSE and K is the optimal number of clusters in the data set. This experiment uses SSE to determine the evaluation value. SSE is defined as follows:

$$\mathrm{SSE} = \prod_{i=1}^{k} \prod_{p \longrightarrow c_i} \left(m_i - p\right)^2. \tag{4}$$

Among them, C_i represents the ith cluster, p represents the sample point in C_i, m_i represents the center point of C_i, and SSE is the clustering error of all samples, representing the quality of the clustering effect.

The K value determined by the elbow method can basically be determined as the optimal number of clusters in the current data set. This is more stable and accurate than the original K-means algorithm that randomly selects the K value, which effectively avoids the randomness of the K-means algorithm itself and improves the stability of K-means.

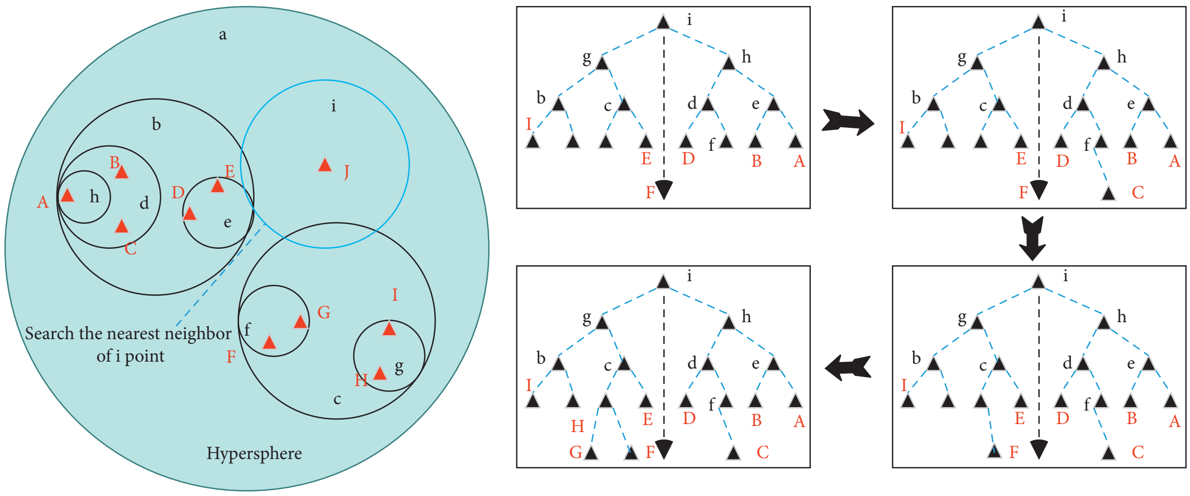
The KD-tree structure and the Ball-tree structure are used to improve the efficiency of the KNN algorithm and the processing power on high-dimensional data, and the K-means algorithm and the KNN algorithm also have the same ideas. Therefore, the KD-tree and Ball-tree structures can also be used in the K-means algorithm to improve the efficiency of the K-means algorithm value and the processing capacity of high-dimensional data.

If the K-nearest neighbors in the data set of a sample belong to a certain category, the sample also belongs to this category. The basic implementation of KNN is linear scanning. At this time, the distance between the current instance of the input and each training instance is calculated. When a training set is very large, the calculation duration is very long and time-consuming, and the efficiency of this method is very low.

The KD-tree model is a high-dimensional indexed tree data structure, which is often used to search the data in space. However, the K-means algorithm is similar to the KNN algorithm and has similarities in the idea of the algorithm; that is, it is necessary to find a point on the data set through this point to find the closest point to it. Therefore, KD-tree can also be used in the K-means algorithm.

Ball-tree is analogous to KD-tree's construction idea. KD-tree uses hyperrectangles for regional division, while Ball-tree uses hyperspheres for regional division. Although the construction process will take more time than KD-tree, performance on high-dimensional data sets will be more efficient. In the Ball-tree construction process, T represents the selected data set, and S represents the current data field. At the beginning of the creation process, the data set T and the data domain S need to be passed in. When there is only 1 data point in the data set, return to that node directly. Otherwise, first, we use the midpoint of all points as the center of the circle and use the distance from the midpoint to the farthest point as the radius to construct the initial circle, and we find the two points node 1 and node 2 with the furthest distance in the initial circle. If they are close to node 1, they are classified as clusters of node 1, and if they are close to node 2, they are classified as clusters of node 2, and then recursively construct small circles. Next, recursively we construct a smaller minimum circle from the solved current minimum circle, until there is only one node left, and it is stored as a leaf node. The structure and search process of Ball-tree are shown in Figure 2.

3.4. Rule Generation and Pruning. The original Top-K association rule mining algorithm is based on the traditional "support-confidence" model, but the traditional "support-confidence" model can only find strong association rules in frequent item sets but cannot filter out strong associations. For rule $A \longrightarrow B$ or $B \longrightarrow A$, the correlation coefficient is defined as



(a) (b)

Figure 2: Ball-tree structure construction and search process. (a) Schematic diagram of structure. (b) Structure search process.

$$\theta(A, B) = \frac{p(A \cap B)}{[P(A) \bullet p(B)]}. \quad (5)$$

The correlation coefficient θ can reflect how much influence "the appearance of item set A" has on the appearance probability of item set B. In practical applications, there are many problems in both positive and negative correlations that deserve our close attention. When θ is greater than 1, it indicates that the former term has a positive promotion effect on the latter term, and the larger the value, the greater the promotion effect. On the contrary, it is an inhibitory effect. When θ is 1, it can be seen from the formula that the occurrence of X has no effect on the occurrence of Y, so we need not consider the case where θ is 1.

$$\theta(A{:}B) = \begin{cases} > 0 & \text{positive correlation,} \\ = 0 & \text{independence,} \\ < 0 & \text{negative correlation.} \end{cases} \quad (6)$$

Therefore, on the basis of support and confidence, the correlation coefficient can only be used to determine the correlation between an item set. Correlation cannot be equal to causality, so the correlation coefficients of the two rules $A \longrightarrow B$ and $B \longrightarrow A$ are the same:

$$\theta(A, B) = \frac{p(A \mid B)}{p(A)} = \frac{p(A \cap B)}{p(A) \bullet [1 - p(B)]}. \quad (7)$$

3.5. Construction of Teaching Mode. Based on the theory of constructivism and blended learning theory, combined with the subject characteristics of English courses and their own teaching experience, this paper proposes an English teaching model based on flipped classrooms, as shown in Figure 3.

Starting from the two dimensions of teacher activities and student activities, this model divides the teaching process into three stages in chronological order: pre-class, in-class, and after-class, showing the relationship between the various links in the teaching process. The pre-class stage of the flipped classroom is mainly to realize the transfer of knowledge, which is mainly composed of the production and preparation of the teacher's teaching resources and the independent learning of the students. The in-class stage is mainly to realize the internalization of knowledge, and the task of English subjects is to complete the use of language. Therefore, in the classroom teaching stage, it aims to realize the application of language knowledge and divides teacher-student activities into answering questions and supplementing. Correction, creation of situations, group collaboration, display and communication, and evaluation feedback are four links, and students are included in the main body of evaluation. Teacher evaluation is combined with student self-evaluation and group evaluation to realize the diversification of evaluation subjects. After class, teachers should reflect on teaching and provide support and guidance for students' review activities to help them complete knowledge remediation or knowledge expansion.

4. Results and Discussion

4.1. Questionnaire Design and Test Results. This research has compiled a "Questionnaire on Collaborative Learning of Students in Flipped Classrooms in Colleges and Universities." The questionnaire is divided into two parts. The first part is mainly about the basic personal information of learners, including gender, grade, subject category, and the length of learning experience in the flipped classroom. It is not only to understand the relevant learning background of the learner, but also to prepare for the differences in these aspects of the influence of different factors in the subsequent data analysis. The second part is the main part of the questionnaire, which mainly reflects the collaborative learning performance of students in flipped classrooms and its influencing factors. Among them, the design of collaborative learning performance items is mainly based on the measurement indicators of collaborative learning performance in the flipped classroom in the previous chapter; the

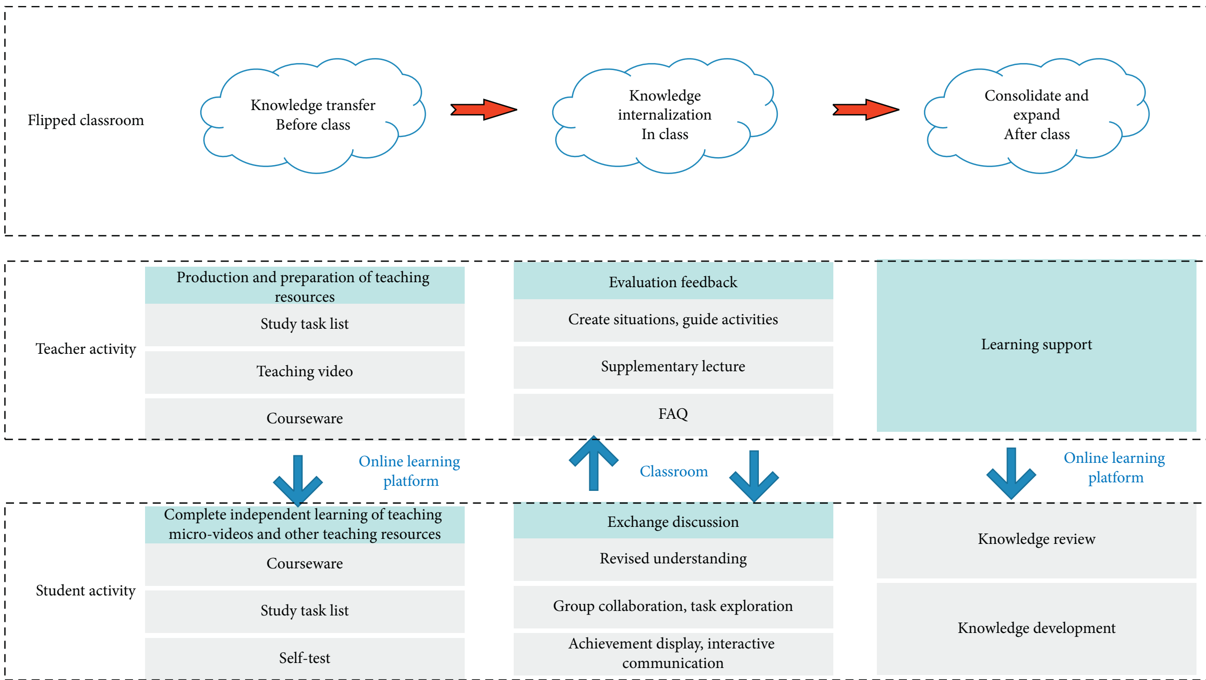


Figure 3: Structure diagram of English teaching model based on flipped classroom.

item design of related influencing factors is mainly based on the 13 influencing factors determined by the learner as the main dividing standard. The questionnaire items are based on the existing research thoughts, written records of classroom observations with the group, and student interviews and exchanges as the standard, and they are discussed with the instructor of the flipped classroom in the class and conceived, designed, and modified. The items in the questionnaire are all single-choice questions. Among them, there are 4 items in the first part of the questionnaire and 35 items in the main part of the questionnaire.

Before forming a formal questionnaire, first, we conduct a trial test. The test subjects of this questionnaire are all students in the class, a total of 50 people. The questionnaire was distributed through the form of online questionnaires, and 50 questionnaires were actually returned. At the same time, the reliability of the test results is analyzed, and the commonly used measurement method is the Cronbach α coefficient method. If the α coefficient is above 0.9, the reliability is very good; if it is above 0.8, the reliability is good; if it is above 0.7, the reliability is good; if it is above 0.6, the reliability can barely be accepted; if it is above 0.5, it indicates that the scale needs major revisions; and if the α coefficient is below 0.5, this indicates that it should be abandoned. The internal consistency of α coefficient in the reliability test result is 0.956, indicating that the overall internal reliability of the questionnaire is ideal. Finally, the test result of the correlation coefficient between the item and the total score is shown in Figure 4.

4.2. Reliability and Validity Test Results of the Questionnaire. Most of the items in the questionnaire of this research are compiled based on literature review, classroom observations, and student interviews. There is no overlap between the formal questionnaire and the test questionnaire. The Cronbach alpha coefficient is 0.953 in total dimensions, indicating that the overall reliability is ideal. The test coefficient of influencing factors is shown in Figure 5. The lowest value of α is 0.65, which is above 0.6 and is acceptable, so the questionnaire reliability is good.

In questionnaire analysis, the validity test is also indispensable. The higher the validity, the more it can reflect the function and purpose of the question to be researched by the questionnaire. Questionnaire validity testing generally includes content validity analysis and structural validity analysis. From the perspective of content validity, the questionnaire in this study is the result of comprehensive review of relevant literature, classroom and group observations, and student interview investigation and analysis. Coordinating the frontline to flip the opinions of teachers, after trial testing and modification, based on the questionnaire formed by enriching the preparation work, it can be trusted in terms of content validity. The structural validity adopts the factor analysis method. First, the KMO and Bartlett sphere test of the data are carried out, and then according to the factor load and cumulative contribution rate, it is considered whether it is suitable for factor analysis. The closer the KMO value ($0 < \text{KMO} < 1$) is to 1, the more common factors among variables and the more suitable for factor analysis. According to the data statistical analysis standard, the KMO value must be above 0.6 before the factor analysis can be done reluctantly, and it can be discarded if it is lower than 0.6. The KMO value is 0.822, which meets the index requirements. At the same time, the approximate chi-square of Bartlett's sphere test is 589.323 ($P = 0.000 < 0.050$), reaching a significant level. There is a correlation between various influencing factors, which is suitable for factor analysis.

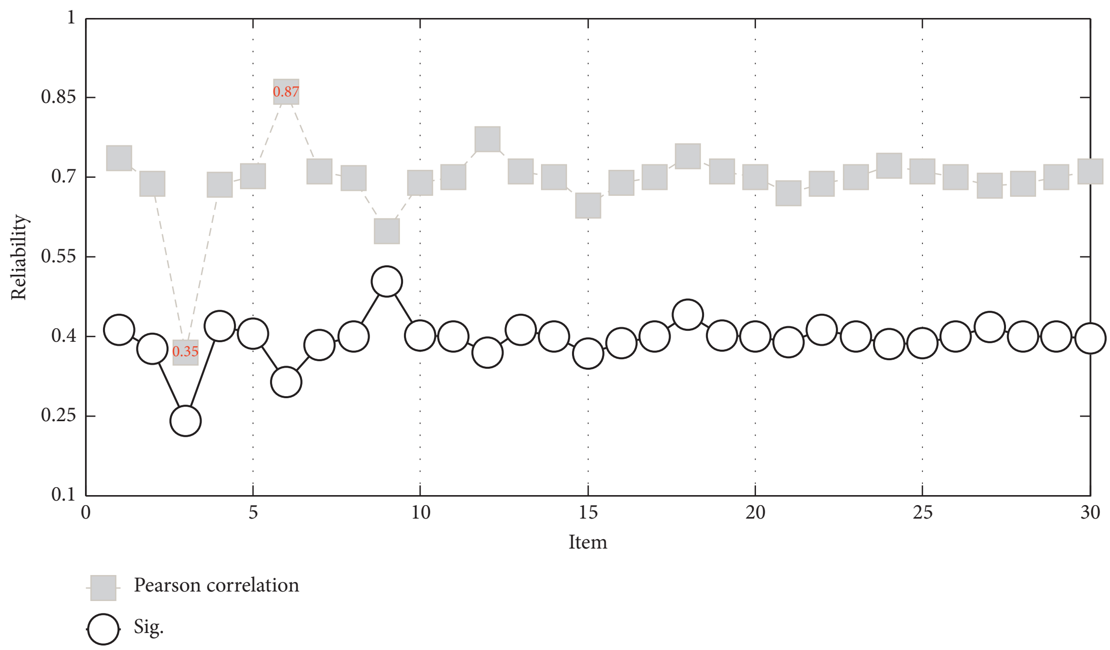


Figure 4: Reliability test of the test questionnaire.

4.3. Descriptive Statistical Analysis of Data. In order to grasp the survey questionnaire data as a whole, descriptive statistics are made on the collaborative learning performance and influencing factor variables in the questionnaire. The basic personal information of the students was learned from 62 valid questionnaires. Among them, 54 boys and 8 girls were first-year university students. Investigators are the first time to come into contact with flipped classroom teaching. The questionnaire uses the Likert five-point scale, and 3 is divided into the middle value. As shown in Table 1, the average value of the observed indicators of collaborative learning performance is greater than 3, which indicates that in flipped classrooms in colleges and universities, the collaborative learning status of students is generally good. Among them, the average value of "individual learning attitude," "group collaborative learning atmosphere," and "group conversation quality" are above 4 points, which is also consistent with the data in the classroom observation record table. There are specific behavioral performances in other aspects, which also reflect the positive attitude of students to the assignment of tasks in collaborative learning.

4.4. Main Effect Test of Data. Using the method of multiple linear regression to determine the mathematical relationship between variables, we determine the path coefficients between variables, highlight which independent variables have significant effects and which ones are not significant, and analyze the effects of main factors on collaborative learning performance. The regression results of influencing factors on individual collaborative learning interest are shown in Figure 6. It can be seen that there is an extremely significant causal relationship between "emotional state," "intention to flip" and individual collaborative learning interest. Students like to learn by video before class first, and then they can deepen and consolidate their knowledge points by solving problems in class. They recognize and accept the teaching form of flipped classroom, and naturally they will accept collaborative learning as a unique learning method in flipped classroom. Through group collaboration, it not only compares and learns other people's problem-solving ideas, but also promotes the relationship between classmates, realizes the effect of group collaboration on course learning, and further stimulates students' interest in collaborative learning.

As shown in Figure 7, with the individual learning attitude as the dependent variable, the influencing factors "emotional state," "online learning input," and "teacher-student interaction" enter the regression equation, and the regression results of the influencing factors on the individual learning attitude are obtained. The regression results show that there is a significant causal relationship between "emotional state," "online learning input," and "teacher-student interaction" and individual learning attitudes.

4.5. Data's Moderating Effect Test. Through the main effect test on the data, the main factors affecting the performance of collaborative learning and their relationship are found, and the path coefficient is obtained. Some research hypotheses have also been verified. Among them, the nonsubject factors "grouping strategy" and "collaborative learning activity design" have no significant influence in the results of this research. Part of the reason is that the test subjects, whether it is a trial test or a formal survey, the students in these three classes only tried the grouping strategy of random grouping and lacked the feeling and evaluation of other grouping methods. Moreover, it was learned in the interviews that most students approve of this random grouping method, so there is no difference in opinions on the issue of "grouping strategy." At the same time, the main effect test results did not indicate the significance level of the

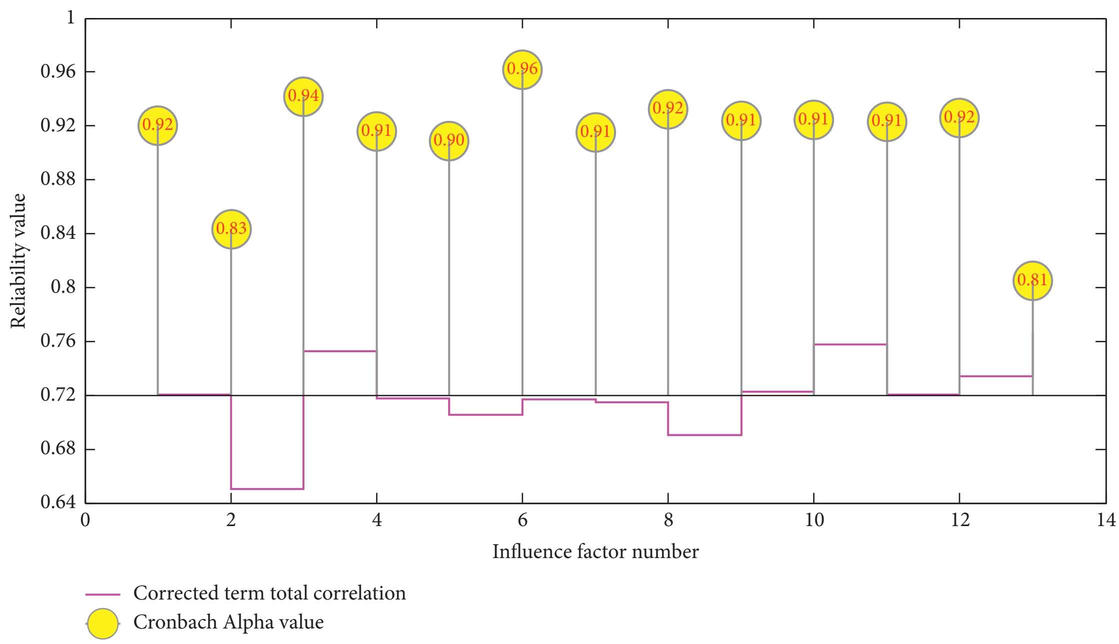


Figure 5: Reliability test of influencing factors.

Table 1: Descriptive statistical results of collaborative learning performance.

Project	Standard deviation	Mean	
	Statistics	Statistics	Standard error
Team task completion quality	0.90	3.50	0.02
Individual performance	0.91	3.42	0.01
Group knowledge sharing	0.92	3.31	0.10
Group conversation quality	0.85	4.11	0.11
Individual task management ability	0.88	3.80	0.12
Individual cooperation ability	0.85	3.78	0.14
Individual expression ability	0.92	3.91	0.15
Individual knowledge	1.10	3.62	0.17
Individual interest in collaborative learning	1.01	3.55	0.10
Group collaborative learning atmosphere	0.92	4.00	0.16
Individual learning attitude	0.89	4.03	0.17

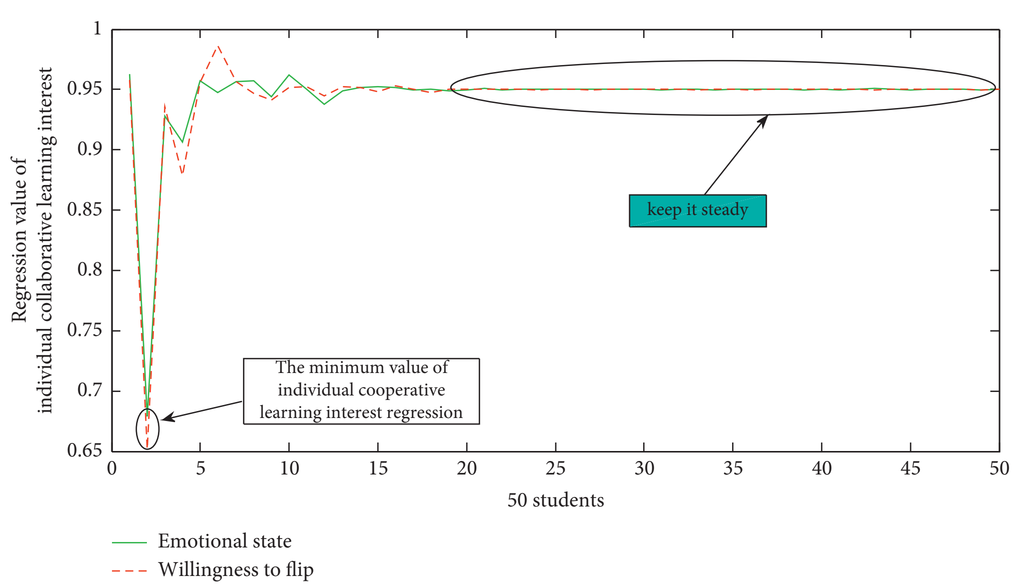


Figure 6: The regression of influencing factors on individual collaborative learning interest.

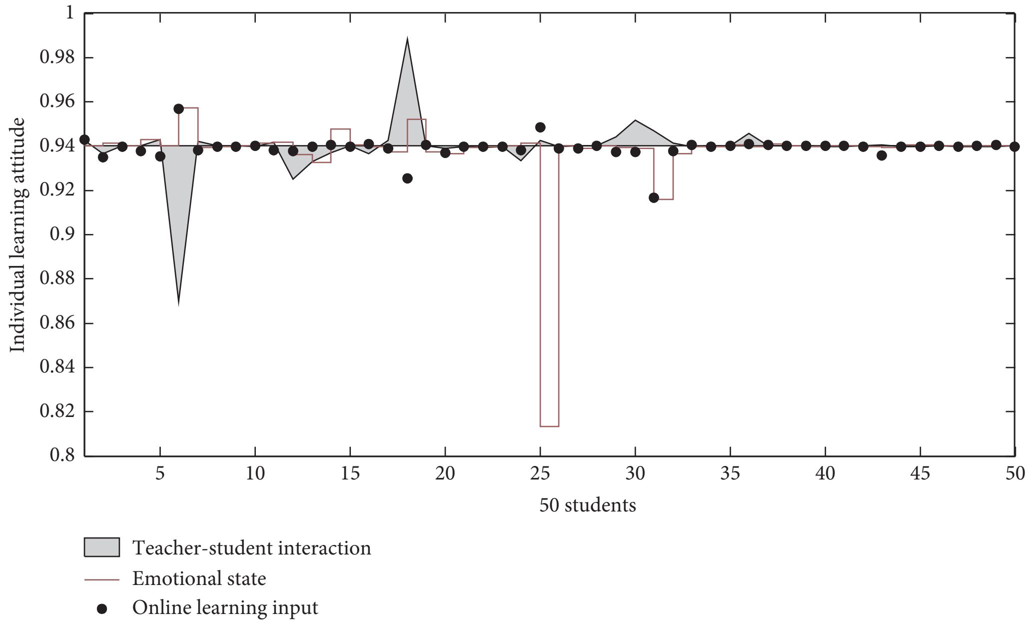


Figure 7: Regression results of influencing factors on individual learning attitudes.

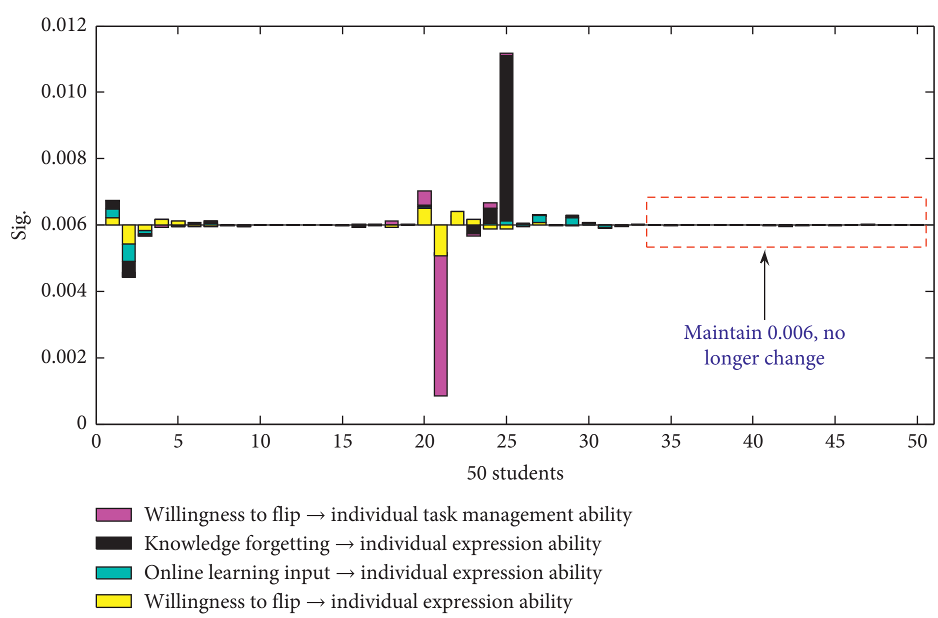


Figure 8: Test results of the moderating effect.

"collaborative learning activity design." It can only show that this factor does not directly affect the collaborative learning performance, but it may change the effect of other factors on the collaborative learning performance to a certain extent.

Moreover, different frontline flipped teachers have different considerations and ideas for the design of learning activities. Due to changes in the teaching objectives and content of each lesson, the design of collaborative learning activities in the classroom is also constantly being adjusted. Therefore, after the main effect analysis of the data, the adjustment effect is analyzed, and the influence of the "collaborative learning activity design" as the adjustment variable is tested, and the path model is improved.

The first step of the moderating effect test is to add the interaction term between the independent variable and the moderating variable as a new predictor variable and incorporate it into the subsequent moderating effect analysis. In order to accurately determine the interaction items, this research first analyzes the correlation between the factors. Here, we mainly examine the correlation between the "collaborative learning activity design" and the main factors. Using SPSS19.0 software to use Pearson's correlation analysis on the data, the relevant results of the respective influencing factors of the main factors and the "collaborative learning activity design" are shown in Figure 8. The significance levels of "collaborative learning activity design" and “flipping willingness,” “emotional state,” “leadership role,” “online learning input,” and “knowledge forgetting” are significantly correlated at the bilateral level. There is a significant positive correlation with turnover willingness, emotional state, leadership role, online learning input, and knowledge forgetting. The design of collaborative learning activities has an obvious moderating effect on collaborative learning performance.

The moderating effect shows that a suitable and high-quality collaborative learning activity design will “magnify” or “accelerate” the influence of the main factor on the performance of collaborative learning. Under the regulation of the collaborative learning activity design, the higher the learner’s willingness to flip, the stronger the individual task management ability and individual expression ability; and the higher the knowledge forgetting, the lower the memory retention, which will lead to lower individual expression ability. The group dynamics theory puts forward that the environment is one of the key group constituent elements, which refers to all the physical environment, social environment, and even individual psychological environment that may have an impact on the group. Therefore, in addition to the physical environment such as the flipped classroom, teachers should also help students construct problem situations through the design of collaborative learning activities, create a social environment that is conducive to learners’ collaboration and interaction, and promote effective learning of students. Therefore, the moderating effect of collaborative learning activity design is the influence of environment as an external factor on collaborative learning performance.

5. Conclusion

This article analyzes the characteristics of curriculum big data and finds that, as a common educational big data, it can better reflect the characteristics of education big data in the teaching work of students. And according to the characteristics of the big data of the course, the deficiencies of the current popular association rule algorithms are analyzed. Through the analysis, it is found that the current association rule mining algorithm has the problem of the target data set being too large and the accuracy of the mining results. Through the analysis, it is concluded that the data set can be clustered through the K-means algorithm to achieve the purpose of reducing the data set, and then the Ball-tree structure in the KNN algorithm is analyzed. After analysis, it is proposed that it can be used in the K-means algorithm Ball-tree structure to improve efficiency. Any high-quality classroom teaching will not lack teacher-student interaction, and as classroom teaching becomes more and more intelligent, teacher-student interaction is not only a simple human-to-human interaction, but also an interaction based on technical support. Regardless of its form, its purpose is to promote teaching and learning. Teachers’ questions in flipped classrooms are more complex and hierarchical. Students’ behaviors after asking questions last longer and the quality of learning is higher. Teacher-student interaction in flipped classrooms improves the quality of the classroom. At the same time, teachers’ speech and behavior feedback give students the feeling of being paid attention to. Appropriate participation of teachers in group collaboration promotes deeper discussions. The essence of teacher motivation is the concrete manifestation of teacher’s speech behavior in teacher-student interaction. Verbal motivation can positively strengthen learners’ learning motivation. At the same time, it can encourage and praise the quality of group results and students’ performance in answering questions, which is conducive to comparison and reflection between groups and students. Therefore, teacher-student interaction and timely and appropriate verbal stimulation are a powerful guarantee for good classroom collaborative learning performance. The starting point of evaluation is to test, and its purpose is to guide and motivate students through learning evaluation. The learning activities in the flipped classroom basically revolve around collaborative tasks, so the evaluation objects, methods, content, etc., are closely linked to each link of the learning activities. The group or individual score is a comprehensive result of objective score, teacher evaluation, and individual or group mutual evaluation of students. Therefore, members listen to the opinions of others and reflect on themselves, while also paying attention to the results of other groups and the performance of collaboration. If the teacher emphasizes the attitudes, methods, and skills of member collaboration in the evaluation content, it will be more conducive to improving the collaborative learning performance of the classroom.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

All the authors declare that they do not have any possible conflicts of interest regarding the publication of this study.

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Research Article

Blockchain Consensus Mechanism Based on Improved Distributed Consistency and Hash Entropy

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To improve the performance for distributed blockchain system, a novel and effective consensus algorithm is designed in this paper. It firstly constructs a more random additive constant through the generation matrix of the error correction code and uses the value of the hash entropy to prove that the constructed hash function can meet the requirements of high throughput and fast consensus in performance. In addition, a distributed consensus coordination service system is used in the blockchain system to realize the synchronization of metadata and ensure the consistency of block data, configuration information, and transaction information. The experiment results show that our proposed strategy can reduce the waste of computing resources, increase the block generation speed, and ensure the fairness of nodes participating in the competition, which is an effective solution to ensure the stable operation of the blockchain system.

1. Introduction

Blockchain is a technique of distributed database which is developed with the applications of digital encrypted currency [1]. A blockchain system has the characteristics of decentralization, nontampering, distributed consensus, provenance, and eventual consistency, which makes it be applied to solve data management problems of the encrusted environments [2].

As a new distributed computing paradigm, it is the combination of point-to-point network, cryptography, distributed storage, and other technologies. It has attracted extensive attention from academia and industry and is mainly used in many fields such as finance, artificial intelligence, Internet of things, medical treatment, and so on [3].

Consensus mechanism is an important part of blockchain technology. It is the key to building trust among untrusted participants. How to make each node efficiently reach a consensus on the effectiveness and consistency of block data in a decentralized system has always been the focus of blockchain technology research [4–7]. Consensus mechanism plays an important role in maintaining the security and efficiency of blockchain [5]. In other words, the correct consensus mechanism can improve the system performance. So far, many different types of blockchain consensus mechanisms have been developed, where the more classic is the proof of work (PoW) mechanism. Its core idea is that each node solves the hash problem through hash-rate competition, to ensure the consistency and consensus security of network distributed ledger. However, PoW needs to consume a lot of computing power and resources. In addition, due to the difference of computing power, there is an imbalance in the probability of packaging accounting right between each node [6].

It is well-known that the consensus mechanism is closely related to the security, stability, and scalability of the blockchain system. The early Bitcoin system adopted the PoW mechanism, which took hash-rate computing power as a means of competition. At the same time, there were also problems such as excessive consumption of computing power, energy-power, and other resources [8, 9]. The proof of stake (PoS) consensus mechanism is an alternative solution to solve the security defects and resource waste of PoW consensus mechanism [10]. *Coinage* is introduced into the PoS mechanism as equity parameter, where the node with the highest equity (*Coinage*) rather than the highest computing power obtains the accounting right of the block. This greatly improves the consensus efficiency and throughput of the blockchain system to some extent but also intensifies the centralization trend for the blockchain system. The PoS mechanism essentially discloses the identity and wealth of stakeholders, so it seems to be incompatible with the cryptocurrency to protect privacy [11].

Consensus mechanism is the algorithm for achieving distributed consensus on transactions in the blockchain system. It is the key to ensuring the consistency of transaction data management by each accounting node [12]. The current public blockchain system generally adopts consensus algorithms on basis of the improved PoW and PoS. The improved PoW algorithm prevents *sybil* attacks [13] by calculating complex mathematical problems, but it causes a decrease in consensus efficiency and a waste of computing resources, resulting in lower throughput and scalability of the blockchain system. With the gradual concentration of computing power, the computing power of a few mining pools can exceed 51% of the entire network's computing power. It can be seen that PoW cannot guarantee against 51% attacks in the mode of computing power aggregation. Although the PoS consensus mechanism can solve the problem of 51% computing power attacks, there is a potential 51% equity monopoly problem, and there are still security issues when the block is forked. The DPoS consensus mechanism selects 101 nodes with equivalent accounting rights through equity voting, which solves the problem of the attacks on the computing power of PoW and the equity of PoS, but there are still 51% attacks on malicious nodes caused by the low participation voting.

It can be seen from the above analysis that the consensus mechanism is one of the factors limiting the development of the current blockchain [14]. For the public-chain system, the consensus mechanism converges the computing power to a small number of nodes, resulting in a significant increase in the probability of 51% attacks. The essential reason is that the computing resources are easier to be concentrated to solve the decomposable centralized problem through the distributed processing environment. In other words, it can be seen that distributed technology brings security problems to blockchain system. In alliance chain and private chain systems, distributed consistency algorithms such as *Pasox* can be used to improve transaction verification throughput and reduce resource consumption. In terms of security, the problems faced by *alliance chain* and *private chain* systems are mainly Byzantine fault tolerance [15], which requires that the number of malicious nodes in the network should be less than 1/3 of the total number of nodes. In addition, a large number of improved consensus algorithms have been proposed to solve the efficiency and security problems of transaction verification in the blockchain system, including the proof of space (PoSp) [16], the authorized Byzantine fault-tolerant algorithm [17], hash graph and hierarchical consensus algorithm [18], etc. The core idea of PoSp is to determine the probability of obtaining the accounting right by proving the amount of data stored by the node, so as to solve the waste of computing resources and improve the verification efficiency. However, there is a potential 51% attack on storage space. Therefore, Hashgraph and HashNet algorithms are mainly aimed at Directed Acyclic Graph (DAG) blockchain system [16]. Hashgraph uses Gossip communication protocol and Byzantine protocol of virtual voting to realize transaction consensus. Its biggest feature is to realize asynchronous consensus. However, its main problem is that multiple rounds of voting verification may reduce the efficiency of consensus.

Consistency is an important issue in distributed blockchain system. The center of the problem is to design appropriate protocols and algorithms so that nodes in the system can only use their own information and neighbors' information under circumstances such as limited information, unreliable information exchanges, communication delays or input delays, and dynamic variations of communication typologies. In order to ensure data consistency and high availability which are the core features of a blockchain system, this paper will use BPFT protocol as the theoretical basis and design high availability scheme, which includes data synchronization, fault recovery, and synchronization. Therefore, our proposed algorithm firstly constructs a more random additive constant through the generation matrix of the error correction code and uses the value of the hash entropy to prove that the constructed hash function can meet the requirements of high throughput and fast consensus in performance. In addition, a distributed consensus coordination service system is used in the blockchain system to realize the synchronization of metadata and ensure the consistency of block data, configuration information, and transaction information.

2. Related Works

2.1. Hash Entropy. The hash function is one of the important data encryption protocols in the blockchain. Since the hash function has irreversible characteristics, it is used to ensure the security and the authenticity of the data, so the data in the blockchain is generally encrypted by the hash function. The blockchain usually uses the *SHA256* function, and its encryption process of the hash function is mainly shown in Figure 1, where Key represents the key of the hash function. After weighting by the hash function, the corresponding hash value is obtained and is stored in the corresponding location in the hash table.

For the rapid positioning of block data, Satoshi Nakamoto [17] proposed a simple payment verification method based on Bloom filter to solve the problems of excessive storage demand and storage redundancy in the Bitcoin system, which allows users to store part of the information to verify the transaction. The Bloom filter is implemented through a hash function, the transaction is weighted by the hash function, and then the information obtained according to the hash function is placed in the location of the hash table corresponding to the Bloom filter. In addition, only the hash table needs to be verified for each transaction. Due to the existence of the hash function, the storage of the blockchain is easier.

Users in the blockchain and their account addresses are encrypted by digital signatures, but for some digital currency

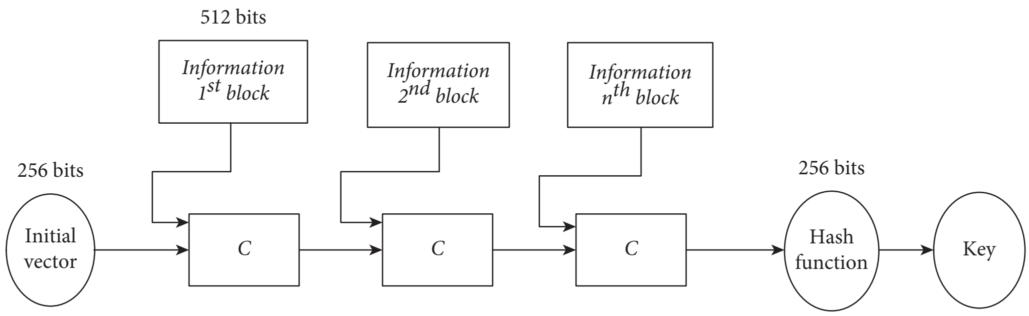

Figure 1: Diagram for SHA256 function.

platforms, users need to make real-name requirements. When real-name users want to cash out their own currency in the blockchain, the own information, the relationship network, and the identity will be exposed, where this behavior greatly affects the confidentiality and security of the blockchain system.

Hash entropy is an encryption algorithm in the blockchain. It is mainly used for miners who package and view transactions, which do not need to know the relevant data of both parties to the transaction and only need to verify the correctness of the transaction according to the hash value of the transaction [18, 19]. These traditional hash entropies require trusted initialization settings, which must be performed by a trusted third party. During the initialization process, some additional variables are often generated. Once these variables are leaked, the attacker can use them to generate false proofs that cannot be detected. It should be noted that the initialization setting is a one-time credible setting for a specific circuit. After the circuit is changed, the initialization setting needs to be performed again.

In order to solve the above problems, some scholars recently proposed several improved encryption mechanisms. For example, Akhtar designed an open and transparent initialization setting to generate a common reference string (CRS) without additional variables in [20]. However, it is still impractical for these new constructions to be applied to the blockchain because their proof size is larger than the traditional construction scheme. Based on hash entropy, an effective privacy protection proposal for account-model blockchain is hiding users' private data such as account balances, transaction amounts, and sender/recipient addresses. More specifically, a hash commitment is adopted to hide account balance and transfer amount, which is a statistically hiding noninteractive commitment scheme with hiding and binding properties.

2.2. Classical Distributed Consensus Algorithm. The distributed consensus mechanism refers to the state machine replication of a group of nodes in the authorized network. It is mainly for some distributed blockchain systems. For example, the Paxos algorithm is mainly designed for the collapsed nodes that may appear in the network; Practical Byzantine Fault Tolerance (PBFT) [16, 21] algorithm can tolerate a certain Byzantine Error node. The classic distributed consensus algorithm has a primary node and other replica nodes. As shown in Figure 2, the PBFT consensus mechanism mainly consists of two parts: The first part is the achievement of a distributed consensus, which is completed by the three steps of preparation, preparation, and commitment; the second part is view-change; when the master node has a problem and cannot process the data request in time, other replica nodes initiate the view after conversion; the new master node starts to work after the conversion is successful. The master node is alternately replaced in a round robin manner. The client uploads the request message m to the nodes in the network, including the master node and other replica nodes. The master node receives the request message m uploaded by the client, assigns the message sequence number s, and then calculates the pre-prepare message $(H(m), s, v)$, where $H(\cdot)$ is a one-way hash function, and v represents the view at this time. The view is generally used to record the replacement of the master node. When the master node is replaced, the view increases 1. The message sender node needs to use its own private key to digitally sign the message before sending the message. The master node sends the pre-preparation message to other replica nodes. The replica node receives the pre-preparation message from the master node and verifies the validity of $H(m)$. In other words, as for view v and sequence number s, the replica node has not received previously other messages. After the verification is passed, the replica node calculates the preparation message $(H(m), s, v)$ and broadcasts it on the entire network. Simultaneously, all nodes collect the preparation message. If the number of the collected legal preparation messages is greater than or equal to $2f+1$ (including its own preparation message), it will be composed of a prepared certificate. If the node collects enough preparation messages and generates a preparation certificate in the preparation phase, then the node will calculate and broadcast the committed message (s, v), where the message m is put into the local log. At the same time, the node collects the committed message in the network. If the number of the collected legal committed messages is greater than or equal to $2f+1$ (including its own promise messages), it will be combined into a committed certificate, which prove that the message m completes the final commitment. The replica node and the master node arbitrarily collect enough

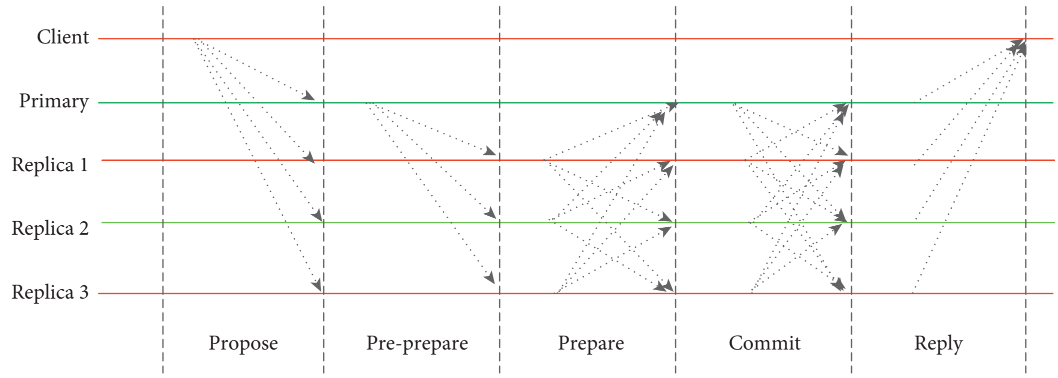

FIGURE 2: Flowchart of practical Byzantine fault tolerance.

committed messages and form the committed certificate, and it is sent to the client as a reply to message m, so the client confirms the final promise of message m.

3. Our Proposed Consensus Strategy

3.1. Problem Description. Given a collection $\{P_1, P_2, \ldots, P_n\}$ of data source suppliers and a collection $\{U_1, U_2, U_3\}$ of data source users, the data source suppliers server group can constitute the data blockchain (DBC) and transaction blockchain (TBC) [17–22]. For a piece of raw data, a certain server node may be the data source supplier, and another piece of raw data is the data user. In addition, a bilinear mapping (q, g, G_1, G_T, e) is used to initialize the system parameters. H: $\{0,1\} \longrightarrow \{0,1\}$ is a one-way, anticollision hash function in cryptography and is instantiated using SHA-256. Let g_1 be a generator different from g in G_1, so the public parameters $\text{Param} = (q, g, G_1, G_T, e, g_1, H)$ can be obtained.

The data source supplier divides the data D to be uploaded into n blocks $d_1, d_2, \ldots, d_n \in Z_p$, where p are a large prime number. In other words, the big data block $D = \{d_z\}(z \in [1, n])$ is the basic unit of data sharing and flow path detection. A data source provider p_i selects a random number x in z_p^* and generates a key pair (pk_i, sk_i), where $pk = g^x$ and the random number x is the private key sk_i.

3.2. Reencryption with Hash Entropy. The compression function of SHA256 mainly operates on 512-bit message block and 256-bit intermediate hash value. In essence, it is a 256-bit encryption algorithm that encrypts the intermediate hash value by using the message block as a key. The data source supplier p_i uses the public parameter *param*, public key pk and data plain-text d_z to obtain the cipher-text after the first encryption. The encryption process is described as follows: A random number r_i in z_p^* is selected, and the reencrypted cipher-text C_z can be calculated from the equation $C_z = (c_1, c_2, c_3)$, where $c_1 = g^{r_1}$, $c_2 = d_z \cdot e(g_1, pk_i)^{r_1}$, and $c_3 = H(H(c_1)\|H(c_1\|c_2))$. And then, cipher-text set $\{C_z\}(z \in [1, n])$ can be obtained, which can be stored into DBC through a consensus mechanism based on threshold cryptography. The decryption operation of data cipher-text first verifies whether the equation $C_z = (c_1, c_2, c_3)$ is true. Otherwise, the data plain-text is calculated by the following equation:

$$d_z = \frac{c_2}{e(c_1)}. \tag{1}$$

When the data source provider p_i wants to share the data D with a data user or a data user buys the data D, p_i needs to generate a reencryption key $rk_{i \longrightarrow j}$ according to the public key pk_i, private key sk_i, and public parameter *param*; p_i will use $rk_{i \longrightarrow j}$ to convert the cipher-text encrypted by pk_i; then $rk_{i \longrightarrow j}$ can be decrypted by private key of p_i. The reencryption key generation process is written as follows:

$$\begin{aligned} rk_{i \longrightarrow j} &= (rk_1, rk_2, rk_3), \\ rk_1 &= g^{r_j}, \\ rk_2 &= g^{-sk_i} pk_j^{r_j}, \\ rk_3 &= H\left(H(rk_1)\|H\left(rk_1\|rk_2\right)\right), \end{aligned} \tag{2}$$

where r_j is random number r_i in z_p^*.

When the data source supplier p_i broadcasts the reencryption key $rk_{i \longrightarrow j}$, the data sharing or delivery process is completed. The conversion of cipher-text can be completed after obtaining the reencryption key $rk_{i \longrightarrow j}$. The specific operations are as follows:

(1) Verify the following two equations. If the above equation does not hold, it indicates that there is a problem with the transmission and retransmission is requested. If the equation holds, continue step 2.

(2) Calculate the cipher-text set $\{W_j\}(j \in [1, n])$ encrypted by the public key pk_j of p_i and convert the cipher-text in $W_j = (\widehat{W}_1, \widehat{W}_2, \widehat{W}_3, \widehat{W}_4)$, where $\widehat{W}_1 = c_1$; $\widehat{W}_2 = c_2 \cdot e(c_1, rk_2)$; $\widehat{W}_3 = rk_1$; and $\widehat{W}_4 = H(H(\widehat{W}_1)\|H(\widehat{W}_1\|\widehat{W}_2)H(\widehat{W}_2\|\widehat{W}_3))$.

If p_i wants to further obtain the plain-text of the data, it only needs to decrypt it with own private key. Firstly, it is verified whether equation (3) is true. If not, return to the initial verification. Otherwise, the plain-text $d_z = \widehat{W}_2 / e(\widehat{W}_1, \widehat{W}_3)^{sk_1}$ of the data block is calculated and output in turn.

Similarly, the data $D = \{d_z\}(z \in [1, n])$ can be obtained to realize data sharing or transaction. After the data sharing or transaction is completed on the DBC, n data transaction record will be formed on the TBC (since the data is cut into n parts) and metadata records will be made. The nodes on the TBC query the authenticity of the transaction through the classic consensus mechanism based on threshold cryptography protocol. When it is true, the transaction will be placed in the transaction pool; otherwise, it will be discarded. Since the blockchain node will verify each transaction, the blockchain itself also has very good traceability, which will prevent the reselling of data and provide users with the function of data-flow path query.

When the data source provider p_i divides the raw data D to be uploaded into n data blocks $d_1, d_2, \ldots, d_n$, some of it could be embezzled. It is assumed that a data block d_k is embezzled data. When the data block is packaged as an *item* and propagates on the TBC network, the node receiving the *item* will check one by one against a standard verification process list. If the data block d_k is a shared data block, we can find the signature of p_s from the signature pool and metadata information, which is to say the operation can complete the flow path query from p_h to p_s. Similarly, it can continue to trace the source of the original data block according to the signature stored in the *item of* p_s. Therefore, log entries only flow from the leader to other servers, which simplifies the management of replicated logs. The reencryption key generation process uses a random timer for leader election, which only needs to add a small number of mechanisms to the heartbeats required by any consensus algorithm, while being able to resolve conflicts simply and quickly. In addition, our improved joint consensus method will allow the cluster to continue normal operation during configuration changes.

3.3. Improved Distributed Consistency. The matrix form of the standard weighted discrete consensus algorithm [18] model is

$$\begin{cases} x(k+1) = p_{\varepsilon w} x(k), \\ p_{\varepsilon w} = I_n - \varepsilon L_{\mathrm{nw}}, \\ L_{\mathrm{nw}} = W^{-1} L_n, \end{cases} \tag{3}$$

where $x \in R^n$ is a consensus variable; ε is the iteration step; $p_{\varepsilon w}$ is a nonnegative random matrix; W is a weighted matrix $W = \mathrm{diag}(w_1, w_2, \ldots, w_n)$, $w_i \geq 1$. When W is a unit matrix, it is the standard average discrete consensus algorithm; n is the number of vertices of the communication topology graph G; I_n is the n order unit matrix; L_n is the corresponding Laplacian matrix, where $L_n = D_n - A_n$. A_n is the adjacency matrix of the graph G and D_n is the dictionary matrix of the graph G.

It can be emphasized that the value range ε of the iteration step is often $0 < \varepsilon < 1/d_{\max}$ in most literature, where $d_{\max}$ is the maximum vertex degree of the graph. The calculation equation of the range is simple, but relatively conservative. When L_n is unknown, the step size can be defined by this range; and when L_n is known, the value range of the iteration step size is denoted as follows:

$$0 < \varepsilon < \frac{2}{\rho\left(W^{-1} L_n\right)}, \tag{4}$$

where $\rho(\cdot)$ is the spectral radius of the matrix.

It can be seen that the improved method takes the state difference between its own unit and the adjacent unit as the adjustment direction. It is a simple autonomous system. Through iterative calculation, the state variable x can be brought to the weighted average of the initial state $x(0)$.

After continuous dynamic adjustment of nodes, the nodes in the alliance chain can achieve high credibility and rapid consensus, which increases the throughput of the blockchain system [23]. Before the consensus preparation stage, the improved consensus mechanism based on threshold cryptography algorithm uses weights to determine the probability of each node participating in the consensus.

The ratio of the current weight to the initial weight is set as the probability distribution of the current node participating in the system consensus service [24], so as to reduce the number of nodes with more downtime and malicious behavior participating in the consensus as a whole, speed up the consensus efficiency and consensus communication process, and optimize the performance of blockchain system. The designed formula is written as follows:

$$P = \frac{w_i}{W}, \tag{5}$$

where P represents the node's participation probability, w_i represents the current weight of the node, and W represents the initial value of the node's weight.

4. Experiment and Result Analysis

4.1. Experiment Configuration. The improvement strategy designed in this paper is coded in *Python 3* on basis of Python *FlaskWeb* framework, and the efficiency of node communication and data interaction is realized through socket network programming and JSON data exchange format [22]. A test blockchain with 8 nodes is built according to the consensus mechanism. Through experiments the block generation time, hash value of the improved consensus algorithm, the influence of the number of node accounting rights, and the influence on the number of node accounting rights are verified. This experiment also compares the results of other consensus algorithms to verify the performance of the consensus algorithm. The configuration information is shown in Table 1.

In the experiment, the client node sends a request to the consensus nodes through the interface, the request contains the required JSON format data, the consensus completion result is stored in the database, and the client query directly queries the database through the interface. In practical applications, the packaged consensus module, storage module, access module, etc. can be directly used to modularize the distributed system, and the systems can call each other through the request interface. In order to verify the superiority of the improved consensus strategy, some comparison algorithms are tested through the blockchain system. In the system, the Random function is used to

Table 1: Configuration information.

Node name	Address	CPU	RAM	OS
Node_1	0fd78b963...	I5-10600	8	Win 10
Node_2	3ed8fr23a1...	I3-6200	8	Win 7
Node_3	4ebde2ed3...	I58700	16	Win 10
Node_4	31cb2cd41...	AMD-6800M	8	MacOS 11.2
Node_5	c1d2ab123d...	I7-6100	4	Win 7
Node_6	38d057840...	I5-10600	16	MacOS 11.2
Node_7	a3c6a92da...	I3-6200	8	Win 7
Node_8	4d6f9fh85...	I5-8700	8	Win 10

randomly determine whether a node has malicious or downtime behavior during the current consensus process.

4.2. Time-Delay Analysis. Time-delay is one of the important indicators to evaluate the performance of consensus algorithms. Time-delay mainly refers to the time it takes for a user to submit a request to reach a consensus. A lower delay can improve the commercial performance of the alliance chain system and complete more business processing.

Different block generation time in the blockchain system means that the size of the transaction information accumulated during this period is different. Different data sizes will directly affect the system's network communication time, so the block generation time has a strong impact on the consensus delay. This experiment uses a combination of multiple node numbers in the consensus network, a single test is performed 10 times, and the average value of the 10 times is used as the final experimental data of the current block generation time to test the impact of different block generation times on the consensus time-delay.

From the above results in Table 2, it can be found that the average delay of our proposed model is 17.59% lower than that of HPoW and 12.1% lower than that of HPoS.

With the increase of generation time, the consensus delay of the blockchain system also increases. When the system block generation time is greater than a certain value, the consensus delay increases exponentially. The increase of block generation time means that more transaction information will be generated in this time interval, resulting in the increase of consensus delay. Due to the multiple forwarding of transaction information in the consensus process, when the amount of data acceptable to the system node is exceeded, the system consensus will be blocked, and the consensus delay increases exponentially. Compared with HPoW and H PoS, our proposed model increases the node reward and punishment mechanism, optimizes the consensus process, and reduces the steps of consensus communication. In the experiment, we assume that the amount of transaction information is fixed, set the same block generation time, and conduct 20 consensus experiments. The simulation machine carries out the control experiment in the real environment. The experimental results of the three algorithms are shown in Figure 3.

Our proposed model reduces the time cost of calculating the random number by dynamically adjusting the difficulty value. The difficulty value is set to 6 and the first 6 bits of the calculated hash value are obtained. The average time of each block is about 1 min. Set up the operation experiment of the blockchain system and record the time spent for each block. In the first 100 blocks, every 10 blocks are interval, and calculate the average value of block time. The statistical results are shown in Figure 4. It can be seen from the experimental results that the fluctuation range of the obtained curve is small. Except that the blocking time of some blocks exceeds 1 min, most of the blocking time is about 1 min. At the same time, the concept of variance is introduced to calculate the variance of the blocking time of our proposed model. The average blocking time of the first 100 blocks is 58.1 s. After calculation, the variance is 45.89. This is because a small part of the data fluctuates greatly. Therefore, the variance is relatively large. However, the experimental results basically meet the requirements, improve the transaction efficiency of the blockchain system, and save a lot of time and computing resources.

4.3. Throughput Analysis. Data throughput is also an important indicator to measure the consensus algorithm. Throughput is a measure to process transactions, requests, and transactions per unit time. In the blockchain, it is expressed as the number of transactions packaged in a unit of time. Figure 5 shows the relationship between the time of different algorithms and the number of packaged transactions. The slope of its tangent line at a certain point indicates the data throughput of the time period. From the slope of the curve, it can be seen that as time increases, the average data throughput gap of the four algorithms gradually increases. The throughput of the proposed algorithm is relatively close to that of the HPoS algorithm, but slightly larger than the throughput of the HPoS algorithm, and is always much greater than the throughput of the HPoW algorithm. Compared with the HPoW algorithm, the throughput of the HPoW algorithm is not as good as the proposed algorithm, so the proposed algorithm has better throughput performance.

In the alliance chain system, the consensus requires multiple complicated communication between nodes. The proposed strategy optimizes the communication process. In the experiment, the improved model is used in a simulated environment, where variables such as block time, number of nodes, and transaction information are set to fixed values. The experimental results of the throughput of the three algorithms can be analyzed in Figure 5, where we also analyze the performance of the proposed strategy without hash entropy. Compared with these comparison algorithms, the consensus throughput of our proposed algorithm is significantly improved.

4.4. Security Analysis. The consensus algorithm mainly refers to the incidence of malicious behavior. In the current complex network environment, ensuring the safe and stable operation of the blockchain is the focus of current research. The security performance analysis of the proposed consensus blockchain system is as follows: Blockchain is a special distributed database system in which each node

Table 2: Average time-delay.

	4 nodes	8 nodes	12 nodes	16 nodes	Average	Result_1	Result_2
PoW	156	168	175	198	172.1	—	—
PoS	148	152	168	174	165.2	7.11%	—
Proposed	129	136	145	152	148.1	17.59%	12.11%

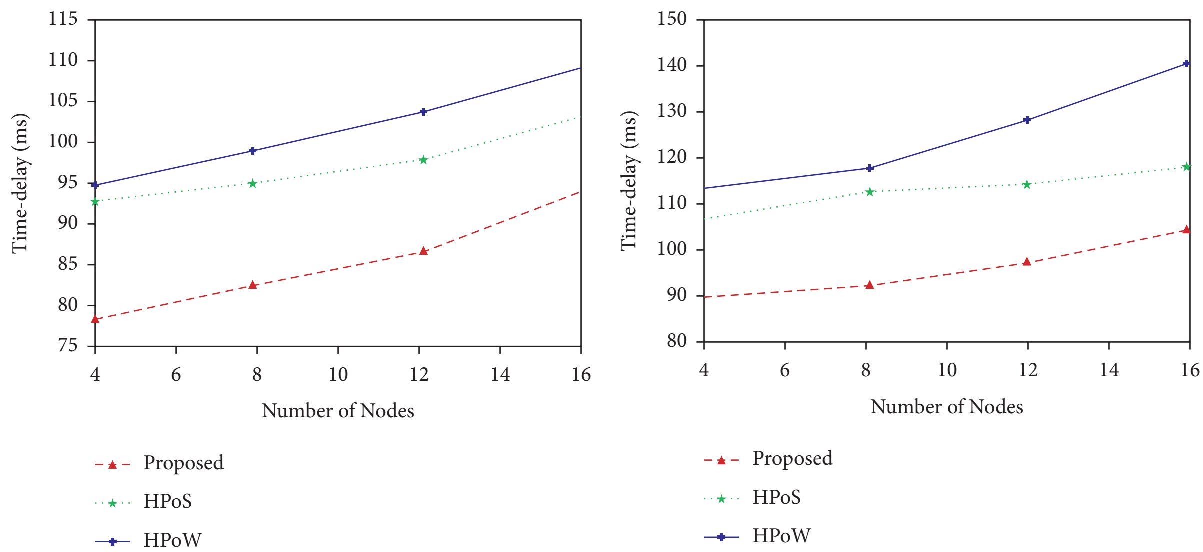

Figure 3: Time-delay for different algorithm. (a) 10 blocks, (b) 20 blocks.

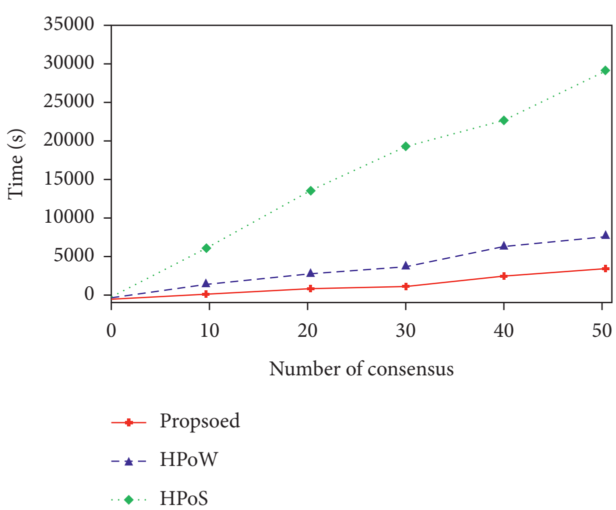

Figure 4: Comparison of consensus times for different algorithms.

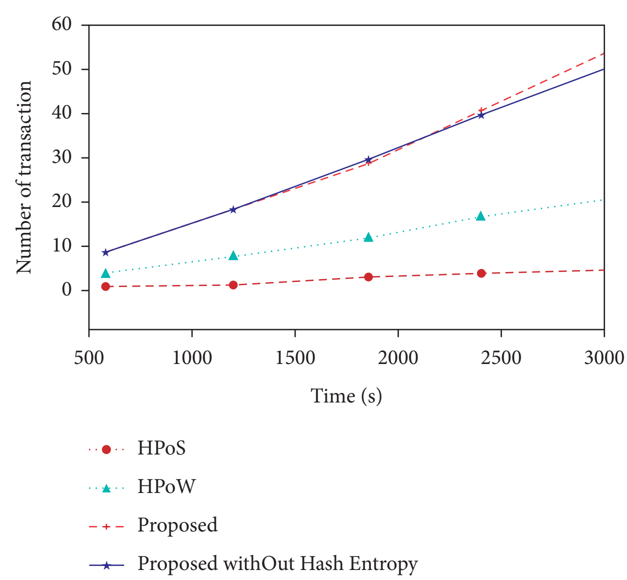

Figure 5: Comparison of the number of transactions for different algorithms.

stores a copy of transaction information. When a node in the blockchain is attacked, other nodes can verify the misinformation data spread by the malicious node so as to ensure the correctness of the entire blockchain system. Therefore, for a single attack on a node, the system has the capability of Denial-of-Service attack.

The proposed consensus algorithm can provide the corresponding consensus participation access mechanism for the nodes in the system. The system can decide whether to participate in the current consensus on the basis of the historical data of the nodes, thereby shielding possible malicious behaviors and reducing the overall number of occurrences of malicious behaviors. The proposed strategy

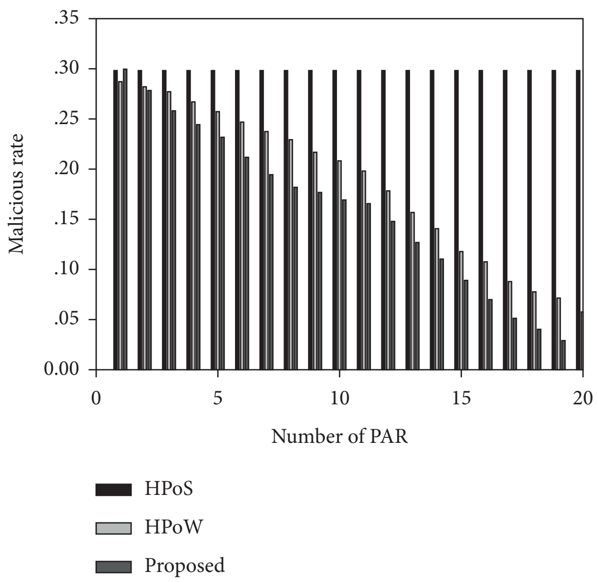

Figure 6: Average malicious behavior rates of comparison algorithms.

can help the blockchain system to improve its robustness, so that the system can operate more efficiently.

Under the improved mechanism, the hash value of the node that successfully obtains the package accounting right (PAR) will be reduced by about half, and it will take a long time to accumulate to reach the level of competition with a higher probability of the package accounting right. If there is a collusion attack, the node will transfer its own hash value to other benefiting nodes. Even if the benefiting node obtains the right to package accounting and obtains the benefits, it does not matter to the node that transfers the value or to the benefiting node.

As shown in Figure 6, the average malicious behavior rates of comparison algorithms are 30%, 18.72%, and 15.65%, respectively. The experimental results show that the improved strategy has obvious advantages in reducing the probability of malicious behavior in the blockchain system and effectively improves the security of the system.

5. Conclusion

The improved distributed consensus algorithm constructs a more random additive constant through the generation matrix of the error correction code and uses the value of the hash function information entropy to prove that the constructed hash function can meet the requirements of high throughput and fast consensus in performance. In addition, a distributed consensus coordination service system is used in the blockchain system to realize the synchronization of metadata and ensure the consistency of block data, configuration information, and transaction information. The experiment results show that the proposed strategy can reduce the waste of computing resources, increase the block generation speed, and ensure the fairness of nodes participating in the competition, which is an effective solution to ensure the smooth operation of the blockchain.

However, our proposed algorithm still needs to be actively explored and improved. The design of consensus algorithm with high-throughput and low-delay performance is the focus of blockchain technology development. The transaction processing capacity of our proposed algorithm needs to be improved. For example, the cross-chain consensus of multichain architecture (including isomorphic or heterogeneous blockchain) can greatly improve transaction performance, which will be one of our research directions in the future [25].

Data Availability

The dataset used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

Acknowledgments

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Research Article

Deep Learning Software Defect Prediction Methods for Cloud Environments Research

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This paper provides an in-depth study and analysis of software defect prediction methods in a cloud environment and uses a deep learning approach to justify software prediction. A cost penalty term is added to the supervised part of the deep ladder network; that is, the misclassification cost of different classes is added to the model. A cost-sensitive deep ladder network-based software defect prediction model is proposed, which effectively mitigates the negative impact of the class imbalance problem on defect prediction. To address the problem of lack or insufficiency of historical data from the same project, a flow learning-based geodesic cross-project software defect prediction method is proposed. Drawing on data information from other projects, a migration learning approach was used to embed the source and target datasets into a Gaussian manifold. The kernel encapsulates the incremental changes between the differences and commonalities between the two domains. To this point, the subspace is the space of two distributional approximations formed by the source and target data transformations, with traditional in-project software defect classifiers used to predict labels. It is found that real-time defect prediction is more practical because it has a smaller amount of code to review; only individual changes need to be reviewed rather than entire files or packages while making it easier for developers to assign fixes to defects. More importantly, this paper combines deep belief network techniques with real-time defect prediction at a fine-grained level and TCA techniques to deal with data imbalance and proposes an improved deep belief network approach for real-time defect prediction, while trying to change the machine learning classifier underlying DBN for different experimental studies, and the results not only validate the effectiveness of using TCA techniques to solve the data imbalance problem but also show that the defect prediction model learned by the improved method in this paper has better prediction performance.

1. Introduction

With the rapid development of computer technology, software applications have expanded to all parts of people's daily lives, creating a situation in which the economy, production, and life are fully dependent on computer software. But software failure can bring about serious or even fatal consequences, especially for high-risk systems. System failure is more often caused by software defects, which are important factors affecting software quality and are potential root causes of errors and failures in the relevant systems. In the early stages of software development, due to the limited processing power of computer hardware, software popularity is not high, and the functions realized by the software are relatively simple, so software was mostly developed in an individualized manner [1]. Although the collected data is concentrated, most of the malicious samples are 64-bit programs, but there are still 417 32-bit programs. However, with the development of hardware technology and the popularity of computers, the scale and complexity of software became larger and larger, and the previous way of software development became increasingly difficult, and, to solve the resulting "software crisis," the way of software development was gradually systematized and engineered [2]. However, in the software development process, the existence of software defects is inevitable due to the limitations of resources and developers' experience. Therefore, the prevention of software defects and the timely correction of software defects have become the reason for the prediction of software defects. People started to collect and use data related to software defects (e.g., data describing the size, complexity, and process of software) and use the data combined with algorithms to construct software defect prediction models for predicting defect information of software.

At the internal level of software, defects are errors or faults in the software development or maintenance process; at the external level of software, defects are violations or failures of the functions that the software needs to perform. Defects in software affect software quality, and early detection of defects and their treatment are important for software quality assurance [3]. However, with the increasing complexity of software systems and the increasing cost of testing, traditional software testing and quality assurance techniques can hardly meet the current needs. If the software development and testing stage can be combined with machine learning technology to deep search, crawl, and analyze the software's historical defect data, to predict and count the distribution and number of defects in the software system in advance to a certain extent, it can better help the quality assurance team to understand the software quality status timely, accurately, and objectively and effectively allocate testing resources to improve software testing efficiency and save testing costs. This can improve software testing efficiency, save testing cost, and guarantee software quality. Through the study of memory analysis technology, a control flow transfer graph generation algorithm based on system calls is proposed. The algorithm is based on the traditional program control flow graph combined with the system call information to automate the generation of system call transfer graph, which can effectively detect and identify malware by using the existing graph neural network model [4]. When it is greater than 0.7, it shows an increasing trend, and the fine-tuned prediction model can show good prediction performance under different sparsity parameters, and the recall rate and F1-measure are better than the performance of the non-fine-tuned prediction model. By mining the software history repository, extracting program modules and metrics, marking whether they contain defects or the number of defects, building software defect prediction models using machine learning and other methods, and then predicting the propensity of defects, defect density, or number of defects for new program modules, software defect prediction technology can be developed [5]. Software defect prediction technology gives software development teams one more chance to retest software defective modules, and, by spending more effort on defect-prone program modules and less on non-defect-prone program modules, the resources of software projects will be better utilized, which can also greatly reduce the human and material resources consumed by testing work, save testing costs, and improve R&D efficiency.

For the core elements involved in software defect prediction techniques, namely, data and algorithms, artificial intelligence plays a great role. When humans first designed programmable computers, they were already thinking about whether computers could become intelligent. Now, artificial intelligence (AI) has many practical applications, is an active research topic, and is flourishing. We expect software to intelligently handle routine labor, understand speech or images, and support basic scientific research. In the early days of AI, problems that were very difficult for human intelligence but simpler for computers were rapidly solved, for example, those that could be described by a set of formal mathematical rules. The challenge for AI is to solve tasks that are easy for a human to perform but difficult to describe formally, such as recognizing what a person says or an image. For these problems, it is often easy for a human to solve them by intuition. Whereas abstract and formalized tasks are among the most difficult mental tasks for humans, they are among the easiest for computers. A key challenge for artificial intelligence is how to communicate nonformal knowledge to computers. Some AI projects seek to hard-code knowledge about the world informal language. Computers can automatically understand this formal language using logical inference rules.

2. Current Status of Research

Currently, the available software defect prediction techniques can be simply classified into dynamic defect prediction techniques and static defect prediction techniques according to the techniques used. Among them, the dynamic defect prediction technique is a study of the entire software system life cycle and predicts the distribution of software defects over time, based on the time when the software failure or system failure occurs, while the static defect prediction technique is based on the size of the software system, loop complexity, and other metric data that have relevance to software defects, as well as the propensity of software program modules to have defects, defect density, or a number of defects prediction [6]. Compared to other machine learning algorithms, the prediction accuracy of SVM is higher, but its algorithm complexity is higher and its operating speed is slower [7]. In addition, since there is no unified theoretical guidance for parameter selection in SVM, many researchers have combined parameter search algorithms with SVM and proposed various software defect prediction models that optimize SVM. Combining the parameter-seeking ability of ant colony optimization algorithm and the nonlinear operation ability of SVM improves the classification performance of SVM; the better global search ability of genetic algorithm is used for the selection of optimal features and the calculation of optimal parameters of SVM, which can avoid the premature sieving of beneficial information in feature selection and further improve the performance of prediction models [8]. It inputs software defect features and historical defect data into the artificial neural network model, compares the error between the output results and the actual results, and corrects the data using a back-propagation algorithm to adjust parameters such as the connection weights of ANNs by an iterative method to continuously optimize and obtain the optimal network parameters [9]. This method has the feature of high prediction accuracy, but the training speed is slow because of the need to iteratively optimize the network parameters. Based on the traditional ANN, the ANN improved first initializing the parameters of the ANN using a particle swarm optimization algorithm and then using a simulated annealing algorithm to modify the weights and thresholds of the network, which effectively improves the accuracy and precision of the software defect prediction model [10].

Different types of software metrics have been proposed, and many machine learning and data mining algorithms have been applied to solve the problems that arise in the process of software defect prediction based on machine learning algorithms [11]. The cost of classifying defective instances as nondefective instances is too high, thus affecting the usefulness of the prediction model; the high redundancy in the software metric and the high similarity between nondefective instances allow the data quality to be improved by methods such as feature selection [3]. The three methods, as researchers imaginatively call them, analyze software testing in terms of its length, volume, and structure, respectively [12]. Dynamic software defect prediction refers to the technique of predicting the distribution of system defects over time based on the time of defect generation or failure. Most of the researchers study static software defect prediction techniques and, in this paper, also the static software prediction techniques are mainly studied [4]. The study of static software defect prediction techniques is divided into three main aspects: first, how to evaluate software defect prediction models; second, for the problem of choosing software metrics, effectively choosing metrics applicable to software defect prediction; and third, which qualitative or quantitative or hybrid models can be applied to software defect prediction [2, 13]. Regarding evaluation metrics, precision, clarity, and sensitivity are frequently used evaluation metrics.

Precision refers to the proportion of correctly predicted modules to total modules, clarity refers to the proportion of defective modules predicted as defective, and sensitivity refers to the proportion of all modules without defects that are correctly classified. These three metrics do not achieve a comprehensive evaluation of a model, but they enhance the understandability of the model and facilitate further summarization of the model to improve it. Of course, in practical defect prediction, testers can identify some defective modules based on some testing rules. Programmers are also able to identify a set of defect-free modules based on their programming experience. Thus, the initially marked defective modules can be obtained through the efforts of testers and programmers. Using limited defect marking data to predict the propensity for defects in other modules, researchers typically use a limited number of defective modules and many unlabeled modules to be predicted to construct a predictive model using semisupervised learning. Semisupervised learning methods have the advantage of being able to use both labeled and unlabeled data to make use of as much valid data information as possible.

3. Analysis of Deep Learning Software Defect Prediction Methods for Cloud Environments

3.1. Deep Learning Prediction Methods for Cloud Environments. Researchers generally agree that there is a link between internal properties of the software (e.g., static code features) and its external performance (e.g., defects) and that developers collect historical data from the same project or from other projects in their own company and similar projects in other companies, from which they extract static properties of the code (usually expressed using software metrics) and thus have data on the relevant features of the software, and then research can be conducted based on statistical methods. Machine learning is devoted to the study of how experience can be used to improve the performance of the system itself utilizing computation [1]. Therefore, the performance of the prediction model is stable, but, from the running time comparison chart, the running time of the prediction model basically increases linearly with the number of trees in the forest. In computer systems, the experience usually exists in the form of data, and therefore the main part of machine learning research is about algorithms that generate models from data on a computer, that is, learning algorithms. Linear regression can be extended to the classification case by defining different probability distributions; and here the continuous random variables in logistic regression obey the coordination distribution, which means having the following distribution function and density function:

$$p\left(y.x^2;\theta\right) = N\left(y;\theta^2 x, 1\right),$$
$$F(x) = \frac{1}{1+\left(-b \pm \sqrt{b^2-3ac}/2a\right)}. \tag{1}$$

A feature is an abstract representation of some property extracted from an entity and can consist of data or text; in this paper, features refer to the software defect feature metric already detailed in the previous section. One very important phase that precedes the construction of machine learning models is feature engineering [14]. Feature engineering is the process by which software engineers apply their expertise and skills to analyze and process the dataset to make feature data more useful for machine learning modeling. Subset evaluation is required after the feature subset candidate table is constructed to evaluate the merits of the subset to select the optimal subset. The evaluation methods include the following: the distance measure in FFS, which analyzes the correlation between features and features or features and classes by commonly used measures such as Euclidean distance and squared distance; the information measure in FFS, which evaluates the strength of interdependencies between features and gives a reference for feature selection; the dependency measure in FFS, which gives the separability of features and classes; the consistency metric, which uses inconsistency rate to select the optimal subset; and the classification error rate metric in WFS, which has higher accuracy in evaluating the subset compared to the metric in FFS but takes more time, as shown in Figure 1.

The stopping criterion controls the generation of subsets, which is related to the subset evaluation criterion or search strategy [6]. The hidden neurons of the autoencoder need to be activated too much, which causes the autoencoder training to be overfitted, so the performance of the prediction model is reduced; but when the sparsity parameter is

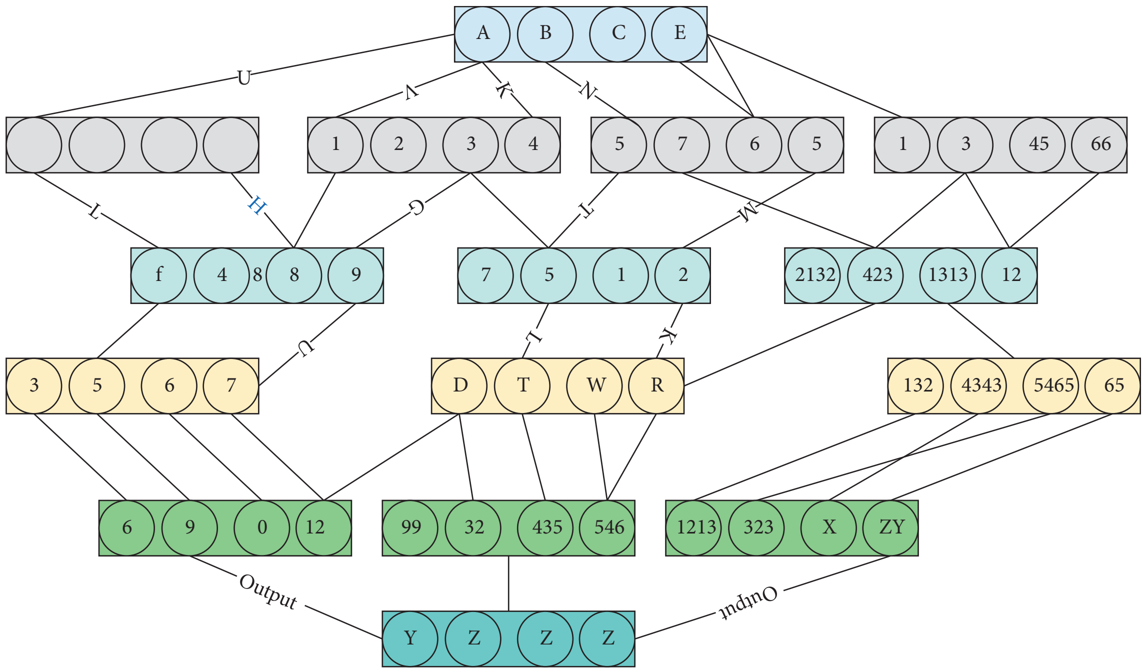

Figure 1: Deep stacking network structure.

greater than 0.7, it means that most neurons in the hidden layer need to be activated this unreasonable setting will destroy the normal optimization of network parameters. The stopping criterion generally includes execution time limit, iteration number limit, and threshold setting. When the global optimal search strategy deals with datasets with many features, its time complexity far exceeds that of other search strategies, and it will greatly affect the efficiency of subset generation, which in turn affects the construction of the whole model while performing a time limit can forcibly end the search, but performing a time limit will affect the optimal subset search performed by this strategy. The stochastic search strategy reduces its time complexity by limiting the number of iterations. The heuristic optimal search strategy prevents the algorithm from entering a dead loop by setting a reasonable threshold.

$$y^3 = f\left(ab_2^3 - \sqrt{a^2 + b^2}\right). \tag{2}$$

Feature extraction is a key step in software defect prediction, and the quality of feature extraction determines the performance of software defect prediction, but traditional feature extraction methods are difficult to uncover the deep-seated essential features in software defect data. Autoencoder models in deep learning theory can automatically learn features from the original data and obtain feature representations of the input data. In this paper, we apply autoencoder to feature extraction for software defect prediction and to improve the loss cost function and sparsity constraint method of autoencoder for its slow convergence of loss cost function and too many sparse regularization parameters, complicated tuning parameters, and so forth. Meanwhile, to reduce the influence of noise on the input data, we propose a software defect prediction based on stacked noise-reducing sparse autoencoder method, which can automatically learn features from the original defect data, extract the required features at each level from the software defect data directly and efficiently by setting different hidden layers, sparse regularization parameters, and noise addition ratios, and then combine with a logistic regression classifier to classify and predict the extracted features.

$$\begin{aligned} \theta^* &= \arg\max \sum_{j+2} nL\left(x_j^{(i)}, y_m^{(i)}\right), \\ J_{SE}(x, y) &= \frac{1}{n} \sum_{y-1}^{n} N\left(\frac{1}{2}\left(\|m\|^3 + \|m'\|_2^3\right)\right). \end{aligned} \tag{3}$$

The inclusion or not of system call execution is added as code block node information in the control flow graph. Some of these nodes do not execute system calls, and this paper is concerned with system call execution information that reflects the intent of the program behavior; such a node is redundant for the graph and needs to be fused with neighboring nodes that contain the system calls. The complexity of the graph is further reduced by generating a control flow transfer graph based on system calls. It propagates labels from labeled data to unlabeled data [15]. The basic idea is that, given a finite amount of labeled data, the labels of the labeled data are propagated through a dense region of unlabeled data, searching for more data with similar properties to the labeled data. A straightforward approach is to compute pairwise similarities between data points and then transform the problem into a harmonic energy minimization problem.

$$\begin{aligned} w_{ab} &= e\left(\left\|a_i - b_y\right\|^3\right)/ - (5\pi), \\ &\max\left\|Xm^2 - y\right\| + \pi m^3 \le 3. \end{aligned} \tag{4}$$

The basic assumption of graph-based semisupervised learning is the cluster assumption. It states that if there is a path that connects two points only through a high-density region, then the two points may have the same class label. In computing nonnegative sparse weights for all samples, a sparse matrix can be constructed. With traditional machine learning classification models, the model is often built based on a condition that the data classification is balanced; however, when the data class distribution is unbalanced, it can affect the classification effect. The Pd value increased by 0.07, 0.07, 0.06, and 0.07, respectively. SOM-ANN uses autoencoders to extract data features and trains neural network classifiers to predict defects in software modules. Classifiers that classify classes based on decision surfaces in the feature space can be affected by unbalanced data class distribution. To reduce the effect of noisy data as well as overfitting, the optimal decision surface considers both the accuracy of the classification and the complexity of the decision surface, also called the structural risk minimization principle. However, if the training sample dataset class distribution is unbalanced, in this case, the number of support vectors is also unbalanced. With the principle of structural risk minimization, the support vector will ignore the effect of rare classes on the structural risk and expand the bounds of the decision. Finally, it will lead to a large gap between the actual hyperplane of training and the optimal hyperplane, as shown in Figure 2.

Based on the actual defect prediction needs, defect prediction models are constructed based on the training set and selected machine learning methods (e.g., plain Bayes, support vector machines, linear regression, etc.); the constructed models can be used to perform defect prediction for non-training-set instances (e.g., unlabeled instances or new instances) in this project; the goal of prediction is to discover whether the instances have defects or the number of defects, and this paper studies the former; that is, the instances with or without defects are predicted. To address the problem that the sparsity parameters need to be set in advance and all neurons in the hidden layer have the same sparsity in the traditional sparse autoencoder, a sparse autoencoder with sparsity constraints based on L1 rules is proposed by penalizing the nonzero activation of hidden neurons in the autoencoder, inspired by the sparsity coding algorithm with L1 rules.

Since the different layers of the stacked noise-reducing sparse autoencoder are learned separately, they must be combined with the classifier to form a complete deep neural network model with fine-tuning of the network parameters. Fine-tuning is done by adjusting the parameters of all layers in the model simultaneously by gradient descent to improve its performance after the pretraining process is completed. Fine-tuning is done by removing the decoding layer of the stacked noise-reducing sparse autoencoder, inputting the features of the last layer directly to the classifier for classification, calculating the loss cost of the predicted class versus the actual class, and iteratively optimizing the network parameters by a back-propagation algorithm using gradient descent to obtain a deep model with optimal network parameters.

3.2. Software Defect Prediction Method Design. Increasing the number of trees will not increase the learning performance. Deep belief networks, an example of the deep learning methods, have the greatest advantage over logistic regression in that deep belief networks can generate more expressive sets of features from an initial set of features. If the input is these generated features rather than the initial set of basic features, the two weaknesses that logistic regression has above can be overcome. Based on migration component analysis to deal with imbalanced data, according to the Introduction, the principle of migration component analysis is that even if the distribution of features in the domain is different, when there are some common underlying factors between the source and target domains, the domains can be put into a potential space to explore the hidden common factors in this way to reduce the domain differences, while the original data characteristics can be retained. Therefore, this paper takes advantage of TCA to map the datasets of two different items to a potential space, and when this potential space is found, a few classes of data from the source item are selected and added to the target item as the training set of the target item, so that the two classes of data in the target item are equal in number, and the imbalance of the dataset is improved at this time, and the loss of information from the deleted data is avoided [16]. The imbalance of the dataset is improved, and the situation of losing information by deleting data is avoided. In contrast, when training the target project dataset (intraproject defect prediction), the dataset needs to be mapped to the potential space first, and then the training model is learned in the potential space. Specifically, for the practical application of defect prediction in this paper, the steps are as follows: suppose that the defect prediction model is to be learned in project when the dataset in project 1 is extremely unbalanced; that is, there is less data with defects and more data without defects, as shown in Figure 3.

Although Sigmoid + SVM has the best checking accuracy, its checking completeness rate is very low. This is especially true for the Mozilla, Eclipse JDT, and Eclipse Platform datasets, but the percentage of defective change instances for these three datasets is about 5%, 14%, and 14%, respectively, for which Sigmoid + SVM has only about 4%, 3%, and 3% find-all rates, while Deeper and the improved DBN method achieve a better find-all rate of over 65%. The results show that Sigmoid + SVM is not good enough for defect prediction, illustrating that imbalanced data preprocessing is necessary and important, and Figure 3 demonstrates that addressing the imbalance in the dataset is critical to the prediction performance of the model. When comparing the improved DBNs with the Deeper approach, it is found that the accuracy of almost all the improved DBNs is higher than the accuracy of Deeper. However, only on one dataset, PostgreSQL, the F-measure metric of the Deeper method is larger than that of the improved DBN, which is due to the relatively low accuracy of the improved DBN method in this paper on the PostgreSQL dataset. However, given the defect prediction setting, the check-all rate is relatively more important than the check-accuracy rate; that is, trying to find as many defective changes as possible

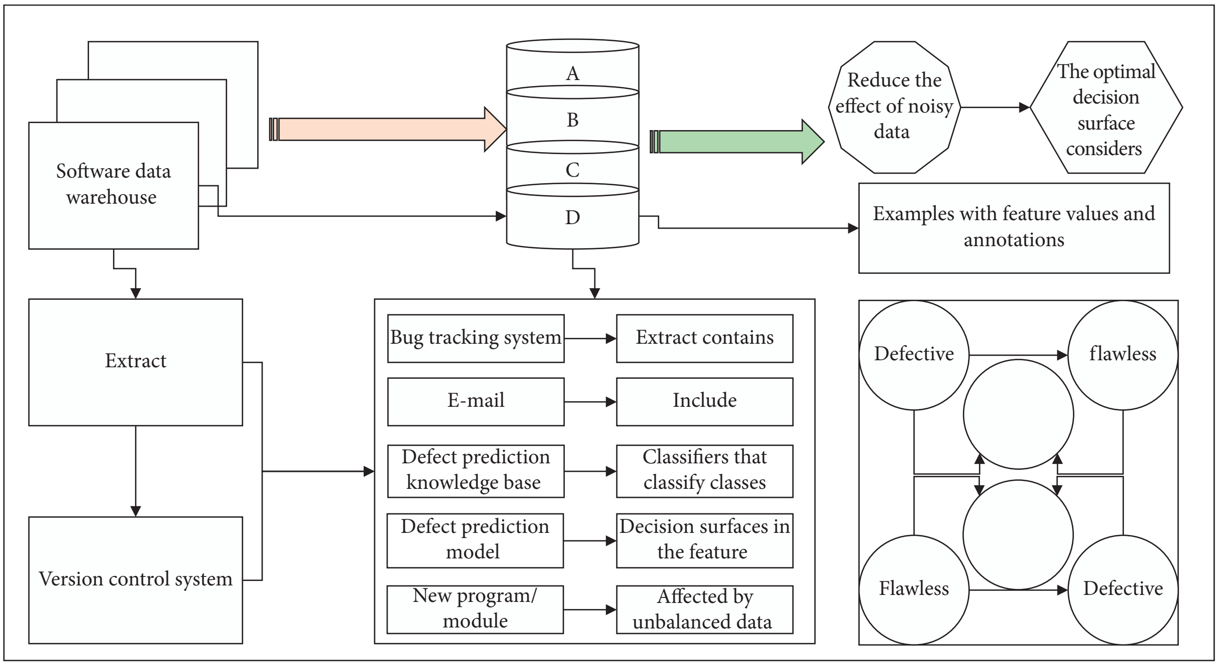

Figure 2: Steps in software defect prediction.

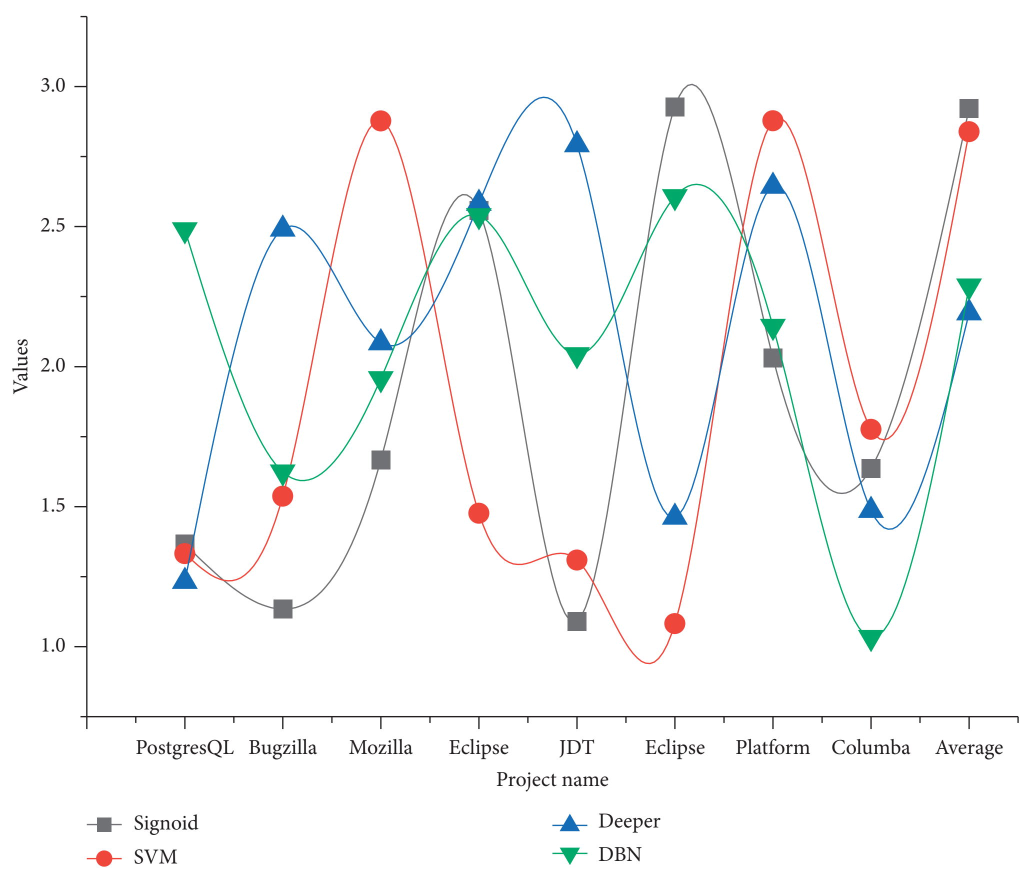

Figure 3: Chakra accuracy.

requires sacrificing some more checking costs to check nondefective instances. Therefore, the improved DBN in this paper is useful and, overall, more effective than the Deeper approach.

The model parallel approach is executed by partitioning the model and putting different computational parts of the model on different machines for the same training samples. For example, the input layer to the first hidden layer of the neural network model is assigned to machine 1, the first hidden layer to the second hidden layer is assigned to machine 2, and the third hidden layer to the output layer is assigned to machine. The disadvantage of model parallelism is that if one of the assigned machines fails, the entire model will stop. The entire dataset consists of a total of 66,301 malware replay images, amounting to 1.3 terabytes of data. The entire dataset was briefly filtered and cleaned before formal analysis. While most malicious samples in the dataset were 64-bit programs, there were 417 32-bit programs in the collection. Although all malware samples run on 64-bit operating systems, all 32-bit images generated by these malicious programs were excluded for data consistency; secondly, the validity of this dataset was checked. By playing back all images and checking the instruction execution during the entire runtime of the malware, it was found that as many as 3462 (5.2%) of the samples did not execute any instruction during the entire runtime. This could be caused by an error during the loading of the malware into memory or by the absence of a necessary component of the target virtual machine operating system of the runtime environment, which prevents the malware from executing correctly. This part of the sample set was also excluded, as shown in Figure 4.

In terms of prediction accuracy, recall, and F1-measure, the prediction model without fine-tuning shows a monotonic increasing trend when the sparsity parameter is less than 0.4, a decreasing trend in the interval of 0.4–0.7, and an increasing trend when it is greater than 0.7. The fine-tuned prediction models show good prediction performance with different sparsity parameters, and the recall and F1-measure are better than the performance of the untrimmed prediction models. To analyze the reason, the number of hidden neuron activations of the autoencoder increases with the increase of the sparsity parameter when the sparsity parameter is less than 0.4, so that the autoencoder can learn the original data with more detailed feature representation and get more essential feature representation of the original data; therefore, the performance of the prediction model increases with the increase of the sparsity parameter. When the sparsity parameter is between 0.4 and 0.7, too many hidden neurons of the autoencoder need to be activated, resulting in overfitting of the autoencoder training, so the performance of the prediction model decreases; but when the sparsity parameter is greater than 0.7, it means that most of the neurons in the hidden layer need to be activated, and this unreasonable setting will destroy the normal optimization of the network parameters, although the prediction model can still achieve the prediction ability. Therefore, prevention of software defects and timely correction of software defects have become the cause of software defect prediction. People began to collect and use data related to software defects and use data combined with algorithms to construct software defect prediction models for predicting software defect information. Although the prediction model can still achieve the prediction ability, the parameters are not obtained through "learning," so the prediction model is an invalid prediction model, and the prediction result is not a valid prediction result. In contrast, the network parameters of the fine-tuned prediction model have been adjusted under the supervision of the classifier, so that the effect of the sparsity parameter setting of the autoencoder on the performance of the prediction model disappears; therefore, the fine-tuned prediction model can show good performance under different sparsity parameters.

4. Analysis of Results

4.1. Deep Learning Predictive Analytics for Cloud Environments. From Figure 5, the nonnegative sparse graph-based label propagation prediction (NSGLP) method has significantly improved the prediction results compared to SVM, CC4.5, and NB; however, compared to the method proposed in this paper, ILR-SDP method, the Pd values of this paper's method based on NSGLP are improved on CM1, MW1, PCL, PC3, and PC4 by 0.09 and 0.08. Because the NSGLP method uses the label propagation method to predict labels on unlabeled data, the predicted obtained labels are used in the trained prediction model, and predicting wrong labels will affect the accuracy of the model. In contrast to the NSGLP method, the ILR-SDP method in this paper uses both real and valid labeled and unlabeled data to train the trapezoidal network. The method in this paper improves the Pd values by 0.07, 0.07, 0.06, and 0.07, respectively, compared to the SOM-SDP method. SOM-ANN uses self-encoders to extract data features and train neural network classifiers for defect prediction of software modules. Compared to these methods, this method uses noise-reducing self-encoders and adds lateral jumps to them. In addition, a small amount of labeled data is used for training. The experimental results prove that the method in this paper does outperform the SOM-ANN method which only uses the traditional self-encoder.

It follows that, in most combinations, JDM can improve the performance of cross-project software defect prediction through a single iteration, and the pseudolabeling refinement mentioned in the method can further improve or consolidate the cross-project software defect prediction performance of the model; the number of convergences of JDM varies from combination to combination due to the differences in both the instance and labeling distributions across combinations; furthermore, not all combinations can be improved by the JDM. One possible reason for this is that the conditional probability distributions used in JDM are computed from pseudoannotations rather than real annotations, and thus the computation of conditional probability distributions may be biased, leading to some degree of degradation in prediction performance. In practical use cases, the efficiency of the detection method and the performance load introduced on the target VM also need to be

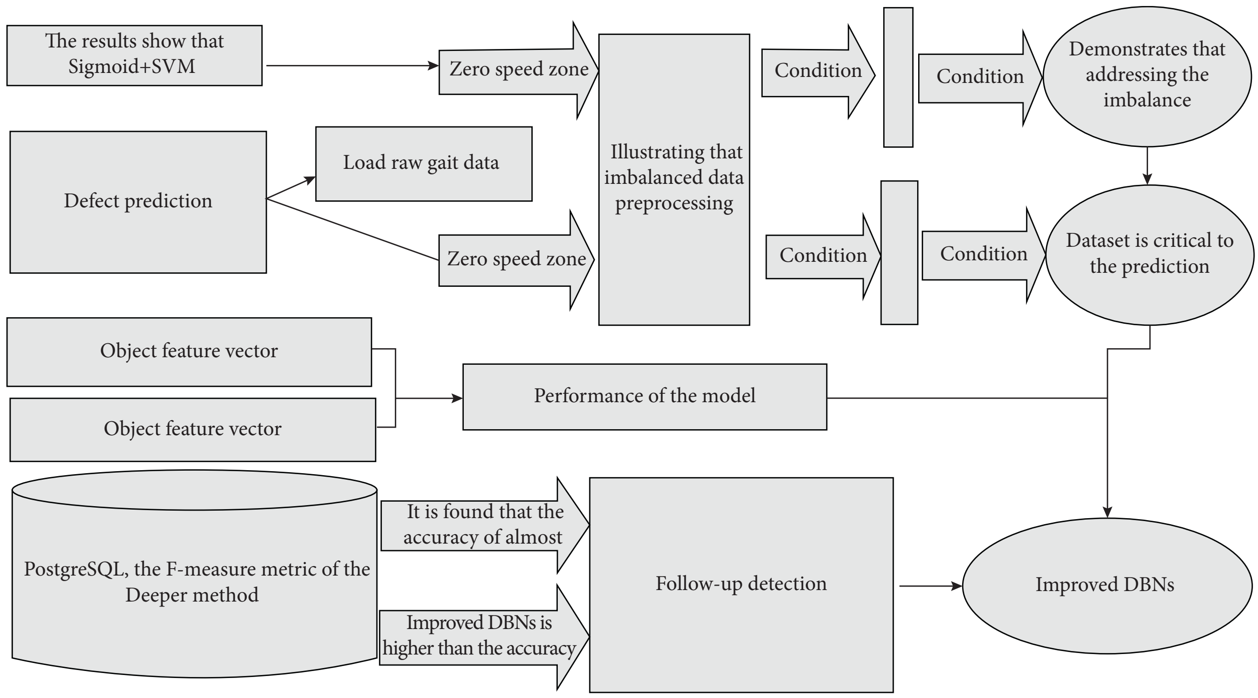

Figure 4: Model parallel framework.

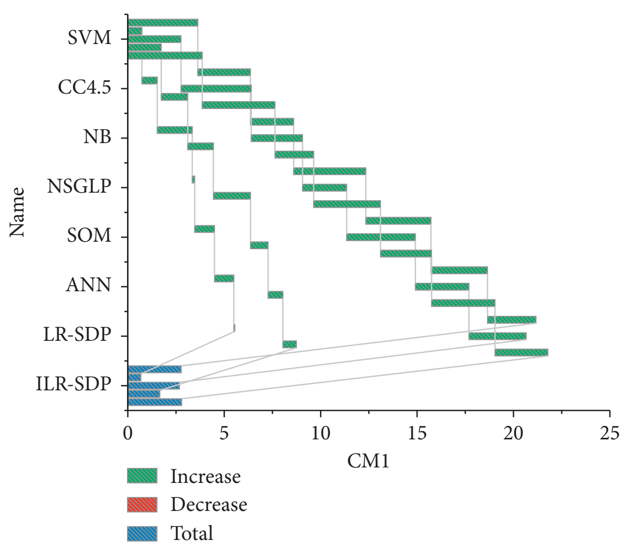

Figure 5: Experimental results of the ILR-SDP method in the NASA dataset.

measured. Improve software testing efficiency, reduce testing expenses, and ensure software quality by assisting the quality assurance team in understanding the software quality status in a fast, accurate, and objective manner and effectively allocating testing resources. If the additional load is high, it may even lead to the unavailability of the target VM. Finally, this paper tests the performance load of each method on the target VM. For the prediction model with the same masking rate, the more hidden layers it has, the higher the correct prediction rate is, and the better the prediction performance in terms of prediction accuracy, recall, and F1-measure is; meanwhile, for the prediction model with the same hidden layers, the prediction performance remains the same when the masking rate is less than 30%, and when the masking rate is greater than 30%, as the masking rate increases, the performance of the prediction model shows a decreasing trend, as shown in Figure 6. Analyzing the reason, for the same masking rate of the prediction model, the deeper the model can obtain the input data deeper feature information, the deeper the layer to obtain the feature information has a stronger feature expression ability, so the more hidden layers of the prediction model prediction performance are better. However, the number of hidden layers is not better but depends on the scale of the prediction model and the training data.

When the prediction model is too deep, it will cause the phenomenon of "gradient disappearance," so that the model training cannot be completed and the prediction results will not be obtained. Therefore, the number of hidden layers should not be increased blindly. For the prediction model with the same number of hidden layers, when the masking rate is less than 30%, the masking noise will remove the noisy data in the training data, which can make the learned prediction model have more robust generalization ability; when the masking rate is greater than 30%, the masking noise will remove the data in the training data that are relevant to software defects, that is, the information that is useful for defect prediction, so the larger the masking rate, the worse the performance of the prediction model. A software defect prediction model is built with the help of machine learning and other methods, and then the defect tendency, defect density, or number of defects of the new program module is predicted. Software defect prediction technology gives the software development team one more opportunity to redetect software defect modules.

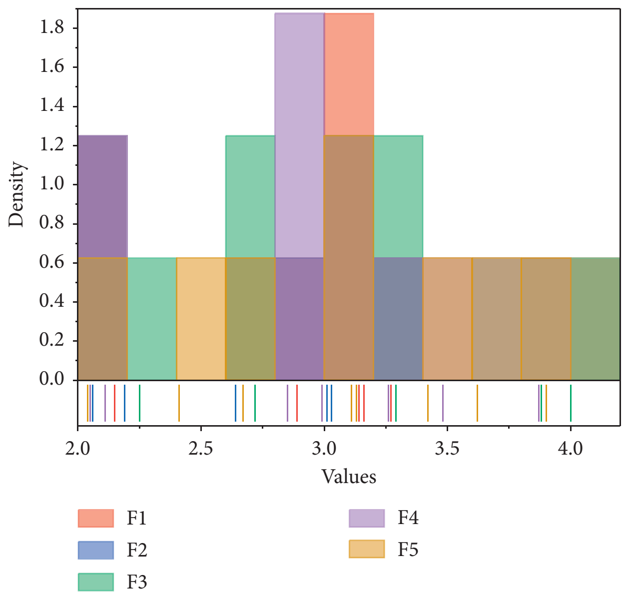

Figure 6: Algorithm performance.

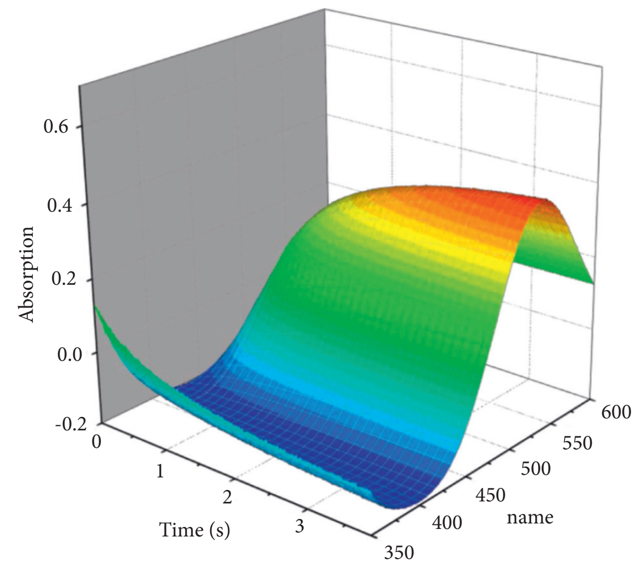

Figure 7: Comparison of F1-measure results for NASA dataset.

4.2. Software Defect Prediction Results. According to the summary of the experimental results, it can be obtained that the experimental metric F1-measure of TNB and the proposed algorithm GFK-SDP in this paper is higher than NN-filter. This is caused by the disadvantage of the NN-filter algorithm in the paper, in which the training dataset is selected during the construction of the algorithm, and this selection process may cause the loss of useful data information, so the final F1-measure value is lower than those in the other two methods. Besides, the GFK-SDP method is significantly better than the TNB method, thanks to the introduction of the geodesic kernel space transformation technique. In the new subspace representation, the distributions of the source and target data are approximated. This effectively reduces the error caused by the inaccurate model training effect due to different data distribution of different datasets and at the same time effectively maximizes the useful feature information in the source and target data. On this basis, the results were effectively improved using the traditional classical classification method, as shown in Figure 7.

Learning-based cross-project software defect prediction techniques have now become a technique of interest to researchers due to the superior performance of stream learning techniques on cross-project software defect prediction problems. For cross-project software defect prediction techniques, it is an important research topic to solve the problem of a different distribution of data features between source and target projects and to effectively mine the shared information between different projects.

People often find it easy to solve these problems by intuition. Abstract and formal tasks are one of the most difficult mental tasks for humans, but they are the easiest for computers. In this chapter, a cross-project software defect prediction method based on geodesic streamlines is proposed, which draws on the knowledge of incremental learning to effectively solve the problem of different data distribution between different projects. The software defect prediction model is based on the cross-project model, and the source dataset is used as training data to obtain the software defect prediction model, and, finally, the obtained training model is used to test the data to be predicted. The main problem is that the data distribution of the source data and the target data are different, as shown in Figure 8.

As can be seen from the figure, for a stacked forest of the same depth, when the number of trees in the forest is less than 200, the prediction correct rate, accuracy rate, and AUC value all show an increasing trend, and the prediction recall rate shows a decreasing trend, while the prediction F1-measure shows a stable performance. To analyze the reason, when the number of trees in the forest is less than 200, the learning ability of the random forest and completely random tree forest in the stacked forest increases with the increase of the number of trees, so that the stacked forest can learn more detailed data information, and, therefore, the performance of the prediction model increases with the increase of the number of trees in the forest. For these three datasets, the recall rates of Sigmoid + SVM are only about 4%, 3%, and 3%, while Deeper and the improved DBN method achieve a better recall rate of more than 65%. When the number of trees in the forest is greater than 200, the learning ability of the random forest and the completely random tree forest in the stacked forest has reached saturation, and increasing the number of trees again will not increase the learning performance, so the performance of the prediction model is smooth, but it can be seen from the running time comparison graph that the running time of the prediction model basically grows linearly with the number of trees in the forest, so the performance of the stacked forest is the best when the number of trees in the forest is 200. The loss cost function and sparsity constraint method of the autoencoder are improved. At the same time, to reduce the influence of noise on the input data, a software defect prediction method based on the stacked noise-reducing sparse autoencoder is proposed; and, for the same number of

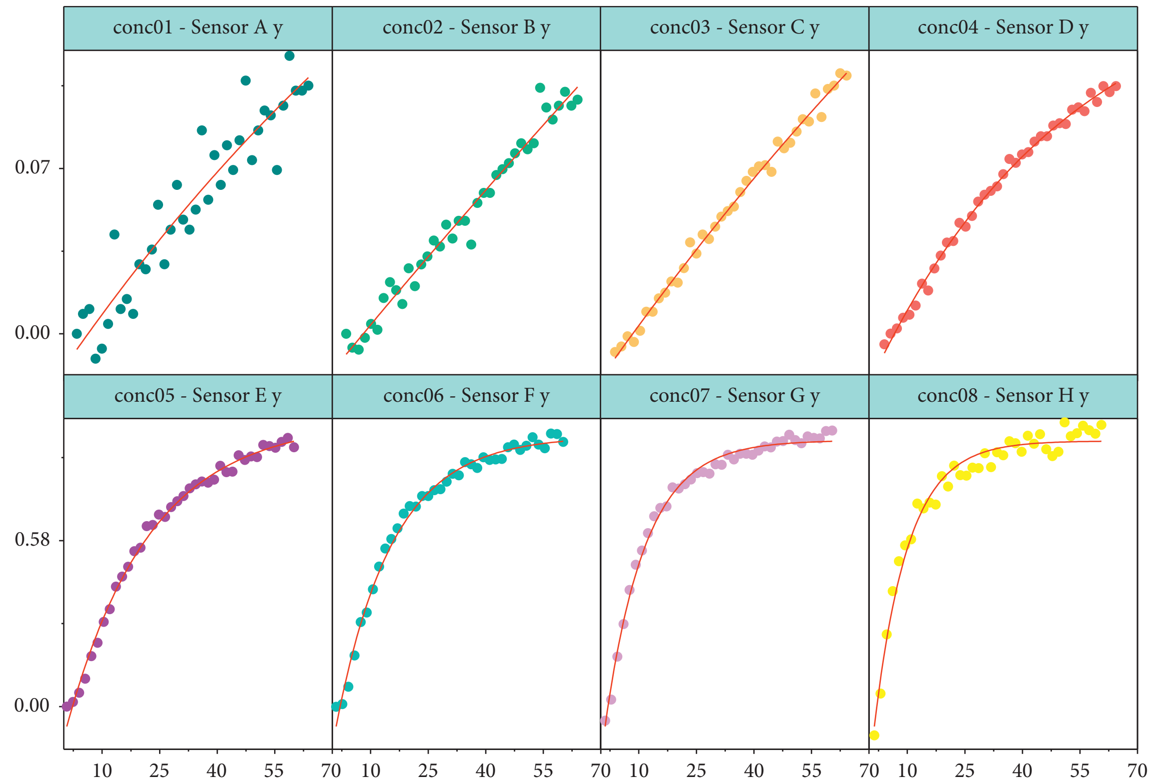

Figure 8: Effect of depth of stacked forest and number of trees on prediction model performance.

trees in the stacked forest, when the stacked forest is deeper, the correct prediction rate remains the same, and the prediction accuracy tends to decrease, but the prediction recall, F1-measure, and AUC values all show an increasing trend, and it can be seen from the comparison graph of prediction AUC values that the performance of the prediction model increases slowly and negligibly when the depth of the stacked forest is greater than three layers so that the stacked forest depth of three layers is the best choice.

5. Conclusion

Deep neural networks require large-scale training data during training, and the task for small-scale data will fail to achieve the desired effect due to training underfitting, and the hyperparameters of deep neural networks are too many, which makes tuning the parameters complicated. To address these problems, the deep forest is applied to software defect prediction, and its feature vector generation method, feature transformation method, and feature enhancement method are improved to address the shortcomings in software defect prediction performance, and the software defect prediction release method based on the deep stacked forest is proposed. The experimental results show that the prediction method based on the deep stacked forest has advantages over the prediction method based on deep forest in terms of prediction performance and operational efficiency. The method of three rounds of manual testing and software defect prediction is used; that is, some program modules are first randomly selected for manual testing, and then the tested program modules are used as training sets to construct software defect prediction models, predict the defect propensity of untested program modules, and then manually test the program modules with defect propensity, and so on. If the class distribution of the training sample dataset is unbalanced, the number of support vectors is also unbalanced. Based on the principle of minimizing structural risks, support vector opportunities ignore the impact of rare classes on structural risks and expand the boundaries of decision-making. After three rounds of manual testing and software defect prediction, the system contains the defect, and the number of defective program modules in the system is reduced to an acceptable level. The combination of manual testing and software defect prediction greatly reduces the number of manually tested program modules, reduces software testing time, and improves software development efficiency. It is practical to apply deep learning methods to malware detection. This paper combines the existing virtual machine introspection technology to migrate all security work outside the virtual machine, which is more secure and efficient; and the use of deep learning methods can also effectively solve the drawbacks of traditional detection methods to make effective detection and early warning of unknown malware variants; differing from single detection methods, this paper effectively combines dynamic/static detection methods.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

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Research Article

A Construction Method of Intelligent Manufacturing System under Industry 4.0 Model

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Starting from the current problems facing Industry 4.0, this article analyzes the changes in the macro and industrial environment that Industry 4.0 faces and explains the problems, opportunities, and strategies for the manufacturing industry in the external environment. First, the reference system of the intelligent manufacturing system, the current status, and the existing problems of industrial production management are analyzed through the investigation of the status quo of industrial production and management. This puts forward the detailed requirements of the industrial intelligent manufacturing system in the data acquisition layer, data storage layer, and analysis and decision support layer and then designs the hierarchical structure of the industrial intelligent manufacturing system. Subsequently, it adopts design methods and lists product manufacturing costs, pointing out that Industry 4.0 requires industrial transformation, and finally proposes the strategic direction of smart manufacturing in combination with the Industry 4.0 network strategy. At the same time, in view of the problems of long parameter measurement time and untimely system feedback in the existing koji-making process, an online parameter measurement method based on network optimization is proposed. On the basis of the neural network, an industrial neural network with double hidden layers and self-feedback of the output layer is proposed. Through algorithm comparison experiments, the proposed parameter prediction model based on industrial neural network has better prediction results and higher accuracy. Finally, a comparison of cost, quality, delivery time, etc., before and after the implementation of Industry 4.0 intelligent manufacturing is carried out. An intelligent solution is proposed, the implementation goal is formulated, and the implementation is gradually implemented in stages, and finally an intelligent upgrade and transformation are realized. It is shown in many aspects that intelligent manufacturing provides a powerful means for enterprises to achieve agility, virtualization, lean, integration, and collaboration, and it can bring efficiency, reliability, and safety to the manufacturing process of enterprises.

1. Introduction

With the gradual rise of customized manufacturing, intelligent manufacturing systems have been widely used, and the resulting intelligent scheduling problems have become a hot research topic [1]. Industry 4.0 focuses on intelligent manufacturing and strives to ensure that the manufacturing industry can continue to develop at a high speed with green, environmental protection, intelligence, and efficiency. The three parts of smart factory, smart production, and smart logistics form the core of Industry 4.0 [2]. Regardless of whether it is smart production or smart logistics, it requires systematic and efficient manufacturing, intelligent allocation of manufacturing resources, and reasonable management of warehousing logistics. These are all multiobjective intelligent scheduling problems. Intelligent scheduling plays a role equivalent to the human brain in intelligent manufacturing, and system modeling and intelligent scheduling are the basis of intelligent manufacturing systems [3]. In particular, the introduction of Industry 4.0 makes intelligent scheduling play the role of the core brain in both smart factories and smart logistics in smart manufacturing, which is the basis of smart manufacturing [4]. Most of the intelligent scheduling problems are combinatorial optimization problems, and their computational theory has been proven to be NP-hard problems. The traditional method of studying combinatorial optimization cannot find the optimal solution of the scheduling problem in polynomial time, and then people began to study to find the near-optimal solution in polynomial time to meet the demand of production scheduling [5].

The purpose of intelligent scheduling is to complete the production tasks of production processing and machine assembly under the premise of satisfying various constraints of the manufacturing system. In the process of intelligent production, due to the frequent changes of production goals, such as the acceleration of product upgrades, the intelligent manufacturing system must also be adjusted according to the new production tasks to ensure that the machine can complete the production tasks with a higher utilization rate [6]. More importantly, in the process of intelligent manufacturing, production is fully automated and unmanned. Once an unreasonable processing arrangement occurs, the machine may collide and cause a safety accident, or two robots may compete for one processing equipment for conflict of loading materials [7]. Therefore, intelligent scheduling plays an extremely important role in the processing safety, equipment utilization, processing cost, and task completion of the intelligent manufacturing system. From the perspective of the manufacturing system, when the number of workpieces manufactured is small or the product is constantly changing, intelligent scheduling is irreplaceable in intelligent production. Intelligent manufacturing system has unique advantages in solving the above aspects [8–10]. And intelligent scheduling is the key to ensuring efficient, reliable, and safe production of intelligent manufacturing systems, so the research on intelligent scheduling has very important practical significance.

With regard to the modeling of intelligent manufacturing system, this paper studies how to use the industrial network to model and analyze the intelligent manufacturing system and proposes the modeling idea from the basic manufacturing unit to the entire manufacturing system. For the research on system model deadlock, we analyze the reachability graph of industrial network system to judge the deadlock situation during system operation and use the established model to study the scheduling method of single task and multitask. In the process of researching batch scheduling, this paper puts forward the idea of combining genetic algorithm and simulated annealing algorithm to form a hybrid algorithm applied to the field of intelligent scheduling. The inspection and evaluation stage mainly analyzes the current situation of K company's internal management and external competition environment and determines the research objectives, planning principles, implementation methods, evaluation index system, and technical methods. Research on the application of Internet of Things technology, industrial robot technology, cloud computing and big data technology in solid wood customization enterprises integrates ERP system, SCM system, CRM system, PLC system, MES system; realizes the interconnection of data and information; and cooperates with each other, promoting each other to form a complete intelligent manufacturing system.

2. Related Work

This article mainly focuses on the research of Industry 4.0 application systems. The research of Industry 4.0 for specific applications mainly focuses on transportation, medical treatment, smart grid, building, and environmental detection. We studied the design method of the transportation-oriented Industry 4.0 system and conducted in-depth research on several key system technologies, such as vehicle perception technology, wireless network protocol, multisensing node information fusion algorithm, and vehicle information feature extraction, and finally realized the transportation Industry 4.0-oriented Vehicle perception and recognition system [11].

Marques et al. [12] looked forward to the application of Industry 4.0 systems in smart medical care and proposed the general development trend of real-time sensing, adaptive response, and remote control medical services. They use sensors installed on the patient to sense vital signs, such as heartbeat and blood pressure. This information can be sent to medical caregivers on a regular basis so that they can provide real-time and effective care to patients. Annanth et al. [13] proposed the microgrid Industry 4.0 system architecture, introduced Industry 4.0 technology into the construction of the microgrid, and gave the microgrid Industry 4.0 architecture model. On this basis, the microgrid Industry 4.0 physical layer, adjustment layer, coordination layer, 6-layer system framework of connection layer, network layer, and application layer were proposed. Hu and Gao [14] researched and designed the building structure health monitoring Industry 4.0 system and studied how to build a reusable architecture so that physical testing and computer simulation testing can be precisely combined, which can effectively support mixed testing of building structures. Wang et al. [15] studied the use of wireless sensor networks (WSN) to construct distributed building structure health monitoring and defect location methods. The paper points out that the existing centralized sensor network structure health monitoring system has problems, such as data collection delay and large network energy overhead, and proposes a distributed processing method. Most of the research in the abovementioned literature is still at the stage of theoretical research on Industry 4.0 architecture, and there is little experience in combining theory with practice. This article will focus on the application of Industry 4.0 theoretical architecture to the design of specific intelligent manufacturing systems.

Tao et al. [16] proposed to combine cloud computing and next-generation Internet technology to study the semantic middleware of Industry 4.0. He Ming et al. [10] studied the Industry 4.0 architecture from the perspectives of system, function, and technology. It also gives the research direction of the Industry 4.0 system and the current challenges. At the same time, a three-tier architecture of Industry 4.0 physical layer, network layer, and application layer was constructed, and related concepts were described and analyzed in depth. Finally, the system architecture was applied to intelligent transportation, which proved the practicality of the architecture. Some scholars have proposed a service-oriented Industry 4.0 architecture, which is divided into a node layer, a network layer, a resource layer, and a service layer. In-depth discussion on the functional modules and technical foundations of each layer is also given, and the future research direction of the Industry 4.0 system is also given. At the same time, it is pointed out that intelligent manufacturing technology is a highly flexible and highly integrated way, through computer simulation of human brain analysis, judgment, and decision-making [17, 18]. Unlike the computer integrated manufacturing system that emphasizes the integration of enterprise material flow and information flow, the intelligent manufacturing system emphasizes the self-organization ability of the entire manufacturing process. It is believed that the intelligent manufacturing system is a combination of intelligence, integration, and automation, with super self-learning ability and self-organizing ability. Some scholars also believe that intelligent manufacturing systems should have self-discipline, self-organization, self-learning, and self-optimization capabilities. Second, from the perspective of industrial applications, we research the development of the intelligent part of the entire manufacturing environment and improve the intelligent manufacturing technology and manufacturing system [19–21].

3. Model Construction of Intelligent Manufacturing System Based on Industry 4.0 Model

3.1. Industry 4.0 Level Analysis. Industry 4.0 is the industrial development strategy of the fourth industrial revolution with intelligent manufacturing as the core. The strategy aims to transform manufacturing into intelligent manufacturing by making full use of information and communication technology and cyberspace virtual systems, a combination of information and physical systems. The main way to achieve this is to fully control the entire process from product demand to manufacturing by building a cyber-physical fusion system, thereby realizing efficient production process management. The Industry 4.0 system is mainly composed of a computing system, a communication system, and a control system, forming the 3C model of the Industry 4.0 system. Figure 1 shows the Industry 4.0 hierarchical topology.

Among them, a large number of sensor nodes and actuator nodes are distributed in the physical world, complete the real-time perception of the physical world, and send them to the computing system and control system through the communication network. The computing system completes various computing tasks required by Industry 4.0 and provides various information services including data mining, statistics, and forecasting.

$$Y(x) = \sum_{x=1,y=1}^{n} p(y \mid x) \times f(y \mid x). \tag{1}$$

The control system uses the data obtained from the analysis of the perception network and the computing system to perform scientific operations on the objects in the physical world, thereby realizing feedback control of the physical world. The communication network of the Industry 4.0 system can be seen as an extension of the sensor network, a combined communication network composed of sensor networks, computer networks, and next-generation communication technologies.

$$\begin{gathered} g(x) - \sum_{i,j=1}^{n} [s(1,i) + s(2,i) + \cdots + s(j,i)]/s(i,j) = 0, \\ \frac{p'(x) - p(x)}{p(x)} - \int \frac{\partial f(x)}{\partial x} \mathrm{d}x = 0. \end{gathered} \tag{2}$$

The activation function of the network has two main functions: first, it can provide a filtering function for the input of the unit node. It is generally hoped that when the correct input is given, the unit is in an active state, near +1. On the contrary, when the wrong input is given, the unit is in an inactive state, near 0; second, no excitation function is applied, and the transfer between neural network layers is just a linear transformation, which leads to insufficient expressive ability of the network model, and the excitation function is the fact that nonlinear factors can be introduced to increase the expressive ability of the model.

$$\begin{gathered} \{\sigma(x,x), \sigma(y,y), \sigma(z,z)\} \longrightarrow \{\varepsilon(x,y), \varepsilon(y,z), \varepsilon(z,x)\}, \\ U = 1/2 \times \int_{\Omega} \sigma(z,x)\sigma(x,y)\sigma(y,z)d\Omega. \end{gathered} \tag{3}$$

During the production process, changes in market demand and raw material supply can be changed and adjusted in time. More importantly, through the intelligent assistance system, employees are relieved. Their work is not on a step-by-step basis, but more energy is invested in innovation to make their work more valuable. This new model is conducive to employees to better integrate their own work, improve work efficiency, and increase work value.

3.2. Construction of Intelligent Manufacturing Platform. Intelligent manufacturing is the integration of manufacturing technology with intelligent technology, digital technology, and network technology in the entire life cycle of product design, manufacturing, operation management and after-sales service, intelligent reasoning, and intelligent decision-making and control to achieve timely response to consumer needs. It is the general term for product design, manufacturing, and supply chain logistics. It is divided into four types: intelligent production, intelligent design, intelligent manufacturing, and intelligent management. The characteristics of intelligent manufacturing are as follows: intelligently perceive and acquire production personnel, production equipment, raw and auxiliary materials, manufacturing environment, and related information in the manufacturing process, interconnection, collaboration, analysis and statistics, forecasting and early warning, decision support, control and execution. In smart manufacturing, the MES system based on smart production is the core component of smart manufacturing.

Figure 2 is the result of dispatching layer allocation of the intelligent manufacturing platform. In the planning phase, the planning and dispatching layer provides material

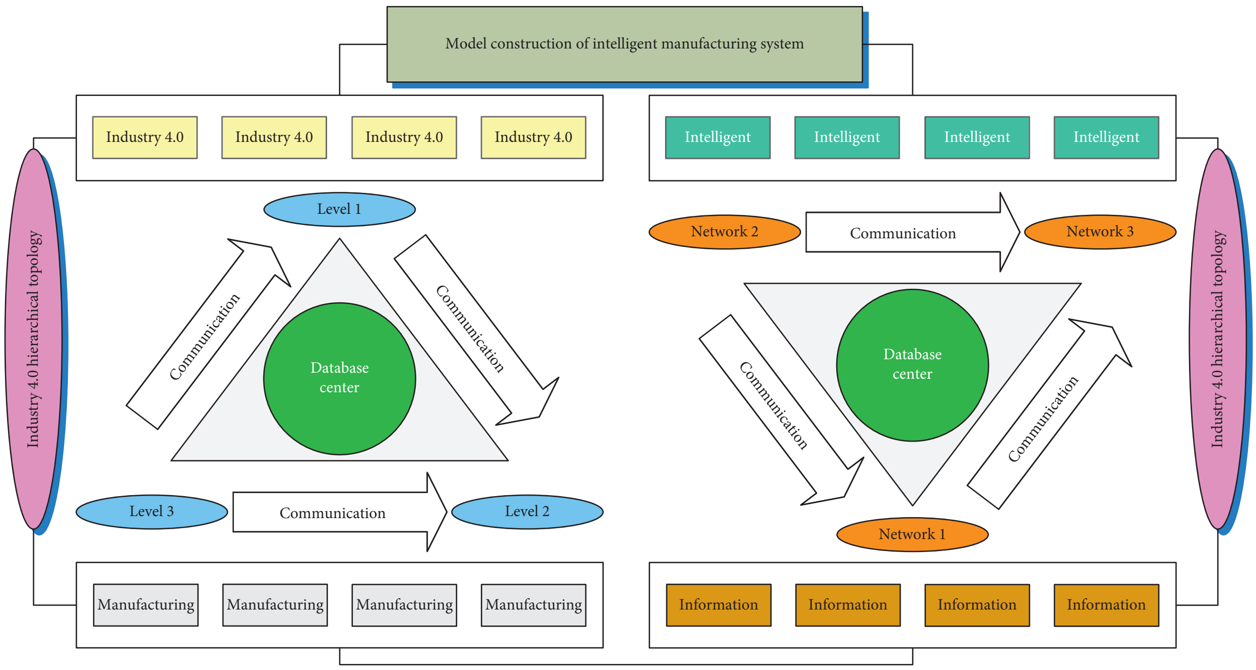

Figure 1: Industry 4.0 hierarchical topology.

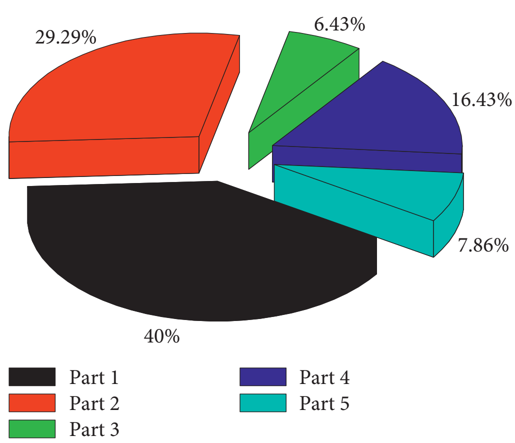

Figure 2: Distribution results of the scheduling layer of the intelligent manufacturing platform.

demand plans to the raw material depots and distribution centers; before production, the execution tracking layer sends out preparation instructions to the raw material depots and distribution centers; during production, the execution tracking layer sends the raw material depots and the control system of the distribution center issues an outbound instruction. The three-level coordination can ensure the timely and accurate supply of materials and ensure on-site production. In the production of refrigerators, the matching of cabinet doors is a difficult problem. Through three-level coordination, the matching of cabinet doors can be effectively achieved. When the planning and scheduling layer issues instructions, the execution tracking layer then issues corresponding process control parameters to the process control layer according to the instructions. At the same time, the process control layer feeds back information to the execution tracking layer, and the execution tracking layer updates the execution status of the work order and feeds it back to the planning and scheduling layer. Through the "three-level linkage," the correctness of the discharge of the library can be checked, and the error-proof interlocking of the execution of the work order can be performed. The basic requirements of automated intelligent manufacturing, data, intelligent equipment, and networks are all prepared to achieve this goal. The data in the entire production process is intelligently collected and dynamically produced to reflect the operation of the entire system in real time. According to the data in the knowledge base, the equipment is automatically maintained on a periodic basis, self-diagnosed, and automatically repaired to avoid the occurrence of failures. Not only the production equipment, but also the overall monitoring of the operation of the entire intelligent system, automatically adjust the production line, realize different production, analyze the results, and predict and prevent systemic failures. We realize interconnection and human-machine integration; integrate resources to quickly respond to market demand; realize intelligent, visual, and fully automated production: extract effective and provide a basis for top-level decision-making; reduce production costs, improve production efficiency, improve product quality, and shorten products cycle.

3.3. Model Weight Factor Update. At the system level, the intelligent manufacturing system is highly integrated with multiple subsystems. It is an organic whole, supplemented by each other, and interconnected with data to jointly achieve the goal of intelligence. At the control level, PLC controls intelligent equipment, system scheduling management, production execution system executes automated tasks, allocates orders, drives equipment, and collaborates to complete the production process. On the execution layer, the execution layer is the real-time perception object of the control layer and the actual terminal monitored by the system layer. Various on-site equipment, materials, areas, lines, etc., use RFlD technology to enable any entity in the system to have a unique identity. The sensing system collects equipment data in the production logistics process in real time and uses big data analysis technology to control the operation of the equipment in real-time parameter. The equipment layer is the entire intelligent equipment, various auxiliary units, which are indispensable for the production site.

Figure 3 is a ladder diagram of the weight of the manufacturing system data supply chain. The internal supply chain communicates with the external supply chain daily to ensure the smooth progress of product production. In addition, the supply chain is integrated to a certain extent through ERP, MES, and other information management systems and through the perception layer (RFID, barcode, GPS, etc.). The network layer (private network, Internet, wired and wireless communication network, etc.) and the application layer (PC, PAD, mobile phone, etc.) seamlessly connect the supply chain to achieve real-time monitoring of the customization process and problem solving appear to give intelligent judgments and make timely responses. Therefore, the corresponding supply chain is basically like a pull supply chain, which drives the production of the workshop by the customer's demand for enterprise products, but it is not a complete pull supply chain model because the design of customized products is not complete. This will involve the MES system and the EI punching system. As the manufacturing execution system, MES is in the middle part, as an intermediate connecting the upper-level planning system and the bottom-level control system. Its main task is the "real-time" production and scheduling of the workshop production process. For nonstandardized and nonmodular production, some parts are often fixed into standard modules for inventory storage through analysis and statistics. When a customer's order contains these modules, they can be used directly, thereby saving parts. The processing time has shortened the delivery time of the order to a certain extent, which not only improves the production efficiency, but also ensures the economic benefits of the enterprise.

3.4. Model Scheduler Design. Manufacturers use the "cyber-physical system" as the framework to build a global industrial network of factory equipment, warehouse management, and industrial products. In the manufacturing sector, Industry 4.0 means that all equipment of an enterprise can independently exchange information. Industry 4.0 is a small smart machine, a small storage system, and efficient product equipment that realize operation and mutual control. Through Industry 4.0, various industrial processes such as manufacturing, engineering, supply chain, and life cycle management are further linked together, and product production is carried out in a brand-new way. When the production instruction reaches the system composed of Industry 4.0, it can flow through the business processes of factories and companies, and the interconnection of equipment can create a derived equipment and product value system, forming a network of manufacturing systems through the Internet of Things. The idea of the Industry 4.0 system includes the whole process of how the physical world information is perceived by the information world in real time and how the information world calculates and makes decisions on the collected data. The ultimate goal of the Industry 4.0 system is to use the existing physical world infrastructure (including perception, computing, and communication hardware and software facilities) to realize intelligent monitoring from the physical world to the information world and from the information world to the physical world to the extent that the information world and the physical world are completely integrated.

The Industry 4.0 system architecture includes three systems: computing system, communication system, and control system. Figure 4 shows the design process of the model scheduler. Among them, the computing system is the central processor of the Industry 4.0 system, responsible for completing all the calculations and decision-making processes of the Industry 4.0 system. At the same time, it can bear the pressure of analysis and processing of massive data and perform fusion processing on multiple data; the communication system is the network transmission part of the Industry 4.0 system, which is responsible for completing the communication and data transmission between devices, from sensors, actuators to information. MES decomposes and refines the production plan information from ERP software to form specific operating instructions. The central network is interconnected; the control system is the central nerve of the Industry 4.0 system, which can perceive all the information in the physical world and respond to the information. Through the control system, the system can be operated according to predetermined rules, and the operation of the system can be maintained or changed. From the perspective of the system view, the Industry 4.0 system is relatively broad and has little guiding significance in practice.

4. Application and Analysis of Intelligent Manufacturing System Model Based on Industry 4.0 Model

4.1. Industry 4.0 Data Preprocessing. The data set mainly includes a training set and a test set. The training set is used to adjust the network connection weight and other internal structures, and the test set is used to verify the results of network training. The training set and test set of the experimental data are from the measured data of the product instrument during the process of making music. At present, 70 sets of data are randomly selected to construct the data set (product parameters are affected by factors such as seasons, and the data set is selected from the measured data in the past two months), of which 60 sets of data are used as the neural network training set, and 10

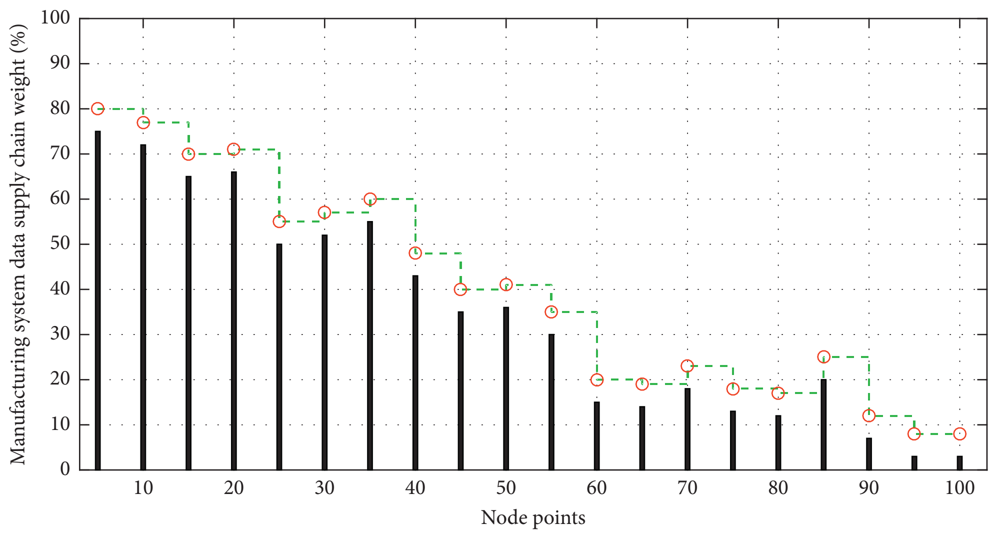

FIGURE 3: The ladder diagram of the weight of the manufacturing system data supply chain.

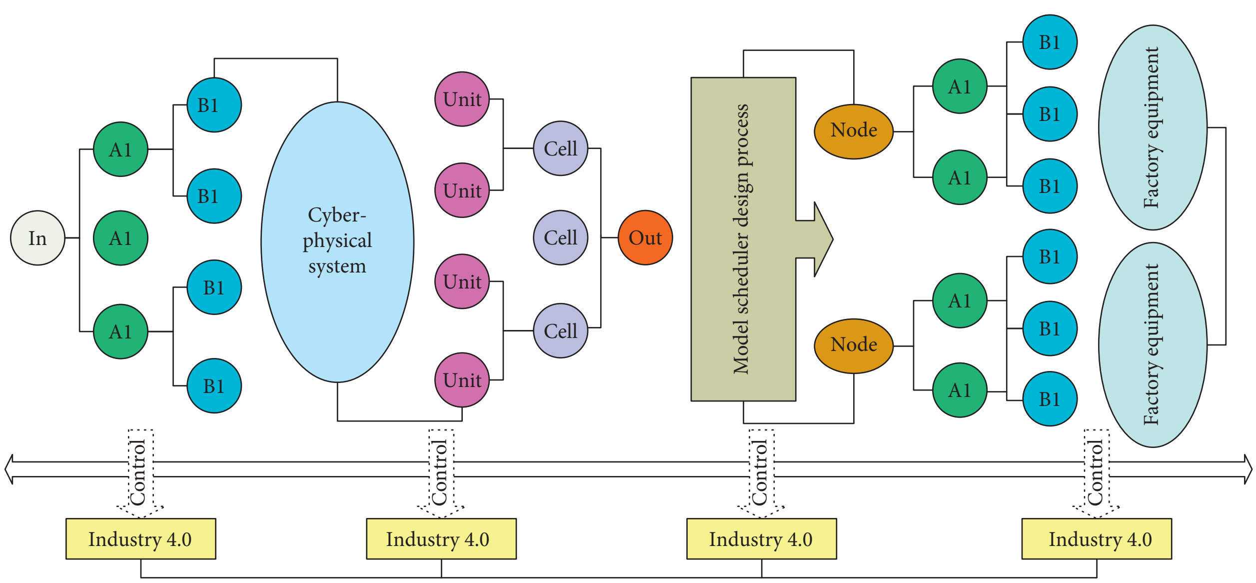

FIGURE 4: Model scheduler design process.

sets of data are used as the algorithm test set. For an example of a scheduling problem, the iterative curves of the optimal solutions of the three algorithms are given. GA-HS1 did not obtain a feasible solution to the problem in the initial iteration stage, so it is not drawn. It can be seen that the order preallocation strategy and the chromosome adjustment link can increase the probability of obtaining a feasible solution so that the algorithm can search in the entire feasible region, and a better solution can be searched in a limited time; that is, GA-HS has better convergence performance. Figure 5 is a histogram of the data convergence effect of the manufacturing system.

According to the basic method of fuzzy industrial network, the network elements of warehouses, tokens, and changes are defined, the topology structure of the network system, namely, the network relationship, is established, and the constraint conditions of the dynamic behavior of the system are given according to the actual production

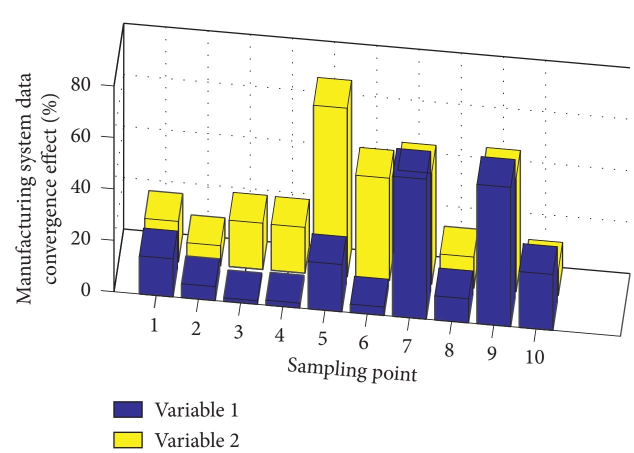

FIGURE 5: Histogram of data convergence effect of manufacturing system.

conditions and production requirements with a fuzzy industrial network energy consumption model suitable for aluminum alloy casting production process. The model describes the main production process and the energy conversion process, that is, the energy consumption process. The dynamic behavior of the system energy consumption is expressed as stimulating continuous changes, and the result of the behavior, the change of the system state, is described by the continuous stock token number, which is the label. The model simulates the relationship between the change in process status and energy consumption process caused by equipment actions derived from operating instructions. Taking into account the interdependence of multiobjectives and decision variables, the aluminum casting decision-making process is divided into two layers. The first layer uses a genetic algorithm based on a mixed code of real numbers and integers to select the corresponding furnace group or furnace group set for each order. The material data of the order provides timely feedback to the EI heart system, and the production plan is effectively connected with the ERP procurement plan and realizes the material analysis of the order, the analysis of the process route and the optimization of the production plan: make a refined production schedule plan for the production order, establish production instructions, and assign the production task list to the corresponding equipment; perform job scheduling, monitor the production progress of the workshop, collect process data, quality data, time data, and other big workshop data, accurately obtain the dynamic data of the workshop; realize order matching and warehouse management; generate various production analysis report; and feedback equipment related information.

4.2. Realization of Intelligent Manufacturing Simulation. Product instrument detection is a continuous measurement process, and data is uploaded every 5 seconds on average. A measurement process takes about 22 minutes, and approximately 260 data are generated. This article uses neural network to predict the product. The data node selects one point every minute and selects the measurement data of the first 5 minutes. At the same time, the quality of the test sample is used as an influencing factor. Then, there are 6 input nodes, and the output value is the measured value of the final wheat product. We select the measured value, sample quality, and final product 5 minutes before the measurement process for network training. Based on the overall structure of the model established above, using the working mechanism of each device in the product group and the actual structure and parameters of the system, the aluminum alloy melting and casting energy consumption model is solidly modeled, and the operating parameter settings under the actual working conditions of the production are used. We set value and operation behavior, equipment action, simulate the dynamic behavior of product group, and compare and verify the simulation result with the actual temperature recorded during the production.

Figure 6 is a line graph of the data training efficiency of the manufacturing system. It can be seen that the deviation

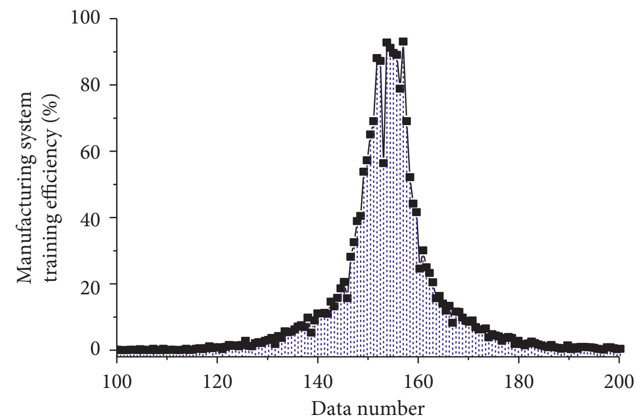

Figure 6: Line graph of data training efficiency of manufacturing system.

of the prediction results of the industrial neural network in 10 experiments is generally small, and the error is the smallest in 7 of the 10 experiments. It can be seen that the overall prediction accuracy of the algorithm is high. In the figure, it can be seen that the minimum cumulative error of the industrial algorithm for 10 experiments is 1.84%, and the average error is only 0.184%, which is far lower than the actual production 0.5% measurement accuracy requirement, which can meet the on-site measurement accuracy requirement. The fluctuation curve of the predicted value and the measured value can further illustrate that among the three algorithms, the industrial forecast result is the closest to the measured result, and the forecast error of the industrial algorithm is generally lower than that of the other two algorithms, and the forecast deviation is basically below 0.3%. A small number of prediction errors are large, but all are below 0.5%, which meets the actual production accuracy requirements. The fluctuation curve of the predicted value and the measured value can further illustrate that, among the three algorithms, the industrial forecast result is the closest to the measured result, and the forecast error of the industrial algorithm is generally lower than that of the other two algorithms, and the forecast deviation is basically below 0.3%. A small number of prediction errors are large, but all are below 0.5%, which meets the actual production accuracy requirements.

4.3. Case Application and Analysis. Deploy the temperature and humidity sensor in the yeast fermentation room; each room deploys 5 sensing nodes, including 3 temperature sensing nodes inside the yeast, which are deployed diagonally inside the room, 1 ambient temperature sensing node, and 1 ambient humidity The sensing node uploads the temperature and humidity data to the system server in real time through the real-time perception of the ambient temperature and humidity and the internal temperature of the curve, so as to achieve the purpose of remote monitoring and decision-making. The settings of the three network nodes are consistent, with 6 input nodes, 8 hidden layer nodes, and 1 output node. The layer proposes a harmony

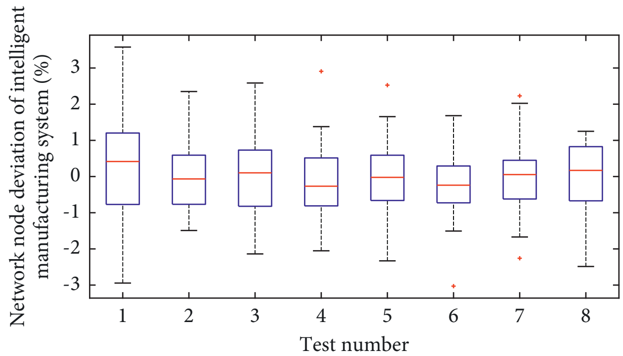

Figure 7: The distribution of network node deviation in intelligent manufacturing system.

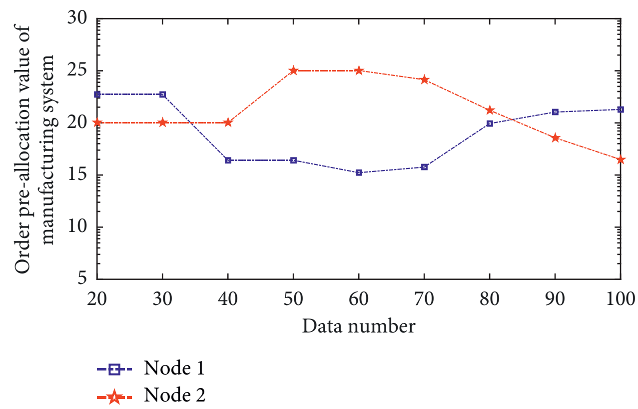

Figure 8: Value distribution of order preallocation in intelligent manufacturing system.

search algorithm based on chaotic sequences to make decisions on the processing order of each order on each furnace group. Each layer selects the same type of state transition function. The hidden layer activation function selects the sigmoid function to improve the nonlinear approximation ability of the model. The output layer selects the linear function to reduce the deviation between the predicted value and the measured value. The convergence condition set in the algorithm experiment is that one of the network training errors mse is less than 0.005 or the number of training iterations is greater than 5000 times. Figure 7 shows the distribution of deviations in the network nodes of the intelligent manufacturing system.

We build the WCC software factory product database, enter the R&D product modules, dock processing equipment, and complete the WCC software's order splitting function. After the dealer's order is verified and confirmed, the order is split through the WCC software, and the BOM list is exported through the E-fang auxiliary expansion interface, including the billing list, the bill of materials, the hardware list, the quotation list, the outsourcing list, and other reports. The implementation of share production management system lays a data foundation. The logo of the fuzzy place P18 represents the change trend of the molten aluminum temperature, which is represented by a solid line, the excitation of the discrete transition T6 represents the feeding action, which is represented by a dotted line, and the excitation of the discrete transition T7 represents the action of the valve, represented by a dashed line. The simulation results show that the change trend identified by the temperature library basically reflects the change trend of energy consumption during this production operation, and the excitation of each change in the model reflects the change of the working state of each device.

Figure 8 shows the distribution of preallocated values of orders in the intelligent manufacturing system. For examples of scheduling problems with scales of 10×5, 10×10, 30×5, and 30×10, the performance comparisons of each link in the proposed method are given respectively. Among them, the parts in bold are examples of the same problem, which are obtained by different methods. The best solution is GA-HS-1 no-order preallocation strategy and chromosome adjustment link and GA-HS-2 no-order preallocation strategy. It can be seen from this that for most scheduling problem instances, the methods proposed in this chapter can achieve better scheduling goals and have greater improvements. The chromosome adjustment link can increase the probability of obtaining a feasible solution, allowing the algorithm to search in the feasible area, and the order preallocation strategy can further improve the quality of the solution. For some small-scale scheduling problem examples, such as the 10×5 scheduling problem example, GA-HS-1 has a higher probability of obtaining the best solution. This is because the order preallocation strategy artificially reduces the search space for understanding; thus, in a smaller solution space, GA-HS-1 can search the entire solution space so that the probability of obtaining the optimal solution is greater. For large-scale scheduling problem examples, such as a scheduling problem with a scale of 30×10, the order preallocation strategy can increase the probability of obtaining the optimal solution within a limited search time.

5. Conclusion

This paper analyzes the intelligent manufacturing system based on Industry 4.0 and divides the task types into two types of problems: fixed delivery and fuzzy delivery according to the delivery situation so that the research of scheduling algorithm is more pertinent. Particularly for the fuzzy delivery problem, through its modeling and analysis, the algorithm becomes a scheduling algorithm that is judged by the processing cost, which is closer to the actual situation, and the application range is greatly expanded. At the same time, a music making intelligent manufacturing system architecture based on Industry 4.0 (a three-tier Industry 4.0 system architecture of perception layer, network layer, and application layer) is proposed to guide the specific design and implementation of the system. We carry out the hierarchical design of the system according to the proposed Industry 4.0 system architecture. The system perception layer design proposes four types of perception node design schemes to complete the comprehensive perception of music making parameters. The system network layer proposes a heterogeneous networking model for Industry 4.0 intelligent making and uses network model simulation to verify the feasibility of the networking model. The system application layer puts forward the software design process of the real-time perception system based on the B/S architecture and designs the key code of the industrial algorithm based on the Java language. The access layer realizes unified access to heterogeneous data sources and heterogeneous systems through data integration components and business integration components. Among them, the business integration component mainly realizes the integration of third-party business systems such as the upper-level ERP system, the bottom-level control system, and the supply chain system. Aiming at the shortcomings of the high coupling between traditional algorithm services and system business, the RPC algorithm service platform design is proposed, which separates the industrial neural network algorithm services and uses remote service calls to perform algorithm predictions, which can greatly improve the reliability of system software. Based on the analysis of the status quo of intelligent manufacturing in the industry, combined with the application of Internet of Things technology, industrial robots, and big data cloud computing technology in the industry, this paper formulates an implementation plan and implementation steps and verifies through examples to build an Industry-oriented 4.0 customized intelligent manufacturing theory system that has certain reference value and guiding significance for the development of intelligent manufacturing industry.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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Research Article

A Matching Degree Management Model of Human Body Shape and Fashion Design Based on Big Data Analysis

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The existing clothing design model lacks the screening link of the human body part index, and the output clothing data are affected by the high correlation coefficient, resulting in large matching errors. Therefore, based on the analysis of human body shape, a management model of matching degree of human body shape and clothing design based on big data is constructed. After processing with big data methods, human body characteristic data used signals as the input layer of a neural network model and the matching degree management model of human body shape and fashion design. The simulation results show that the built-up model has a matching error of less than 5%, which can effectively improve the matching of human body shape and clothing design.

1. Introduction

In fashion design, all functions would be fully displayed on the human body. Based on this, the human body's posture and clothing style composition are complementary and integrated, and they cannot be designed separately [1–3]. Body posture is the theoretical basis of garment style composition, and garment style composition is the ultimate result of showing the smart charm of body posture. Based on the era of big data, the massive growth of data capacity and diversity prompted the use of data mining technology in all areas of mass data analysis. With the increasing demand of personalized clothing design, quickly matching fashion design with human body shape is a beneficial attempt of big data technology and neural network algorithm in the clothing industry. This intelligent fashion design solution can quickly meet the fashion needs of customers [4–6].

Neural network technology has gradually received widespread attention in the garment industry [7]. According to the research, Wang et al. [8] analyzed the apparel style composition under different timing of BP neural network integration and discussed the application of neural network technology in the apparel industry, including material usage calculation, size recommendation, comfort analysis, etc. Liu et al. [9] applied BP neural network technology to men's suit size range setting, researched and analyzed the factors that affect the proposed model, and obtained the optimal size range setting. But the above model only calculates the data of fashion design, not considering the problem of overfitting in the process of model calculation. So, the resulting error of the fashion design model is large.

Therefore, based on the study of human body shape, the human body index data are collected by the big data method, and the neural network integration method is used to construct the matching degree management model of human body shape and clothing design, so as to realize the automatic mapping matching between human body and clothing design and lay a technical foundation for the mass customization and tailoring of clothing.

2. Network Model of Fashion Design

2.1. Big Data Collection of Human Body Index. Based on the aesthetics of the human body, the images of the human body structure, bone, muscle, shape, and other aspects are collected by the big data method, and the morphological characteristic signals of the upper part of human body are extracted and decomposed into

$$a = \frac{\beta^2 \log_3 \lambda}{\eta} + \sqrt{\beta}, \tag{1}$$

where β represents the waist of the human body, λ represents the shoulder width of the human body, using centimeters as units, and η is the number of sampled signals.

Based on the collected human leg images, the morphological characteristic signals of the lower part of the human body are extracted, and the decomposition formula is as follows:

$$B = \frac{\mu^2 \log_3 \gamma}{\eta} - \gamma, \tag{2}$$

where μ refers to the length of human legs and γ refers to the data on human height. Combining the morphological characteristics of the upper half of the human body and the legs, the integral surface model is constructed as follows:

$$c = \frac{\mu^2 \log_3 a + \beta^2}{\eta} - \log_2 \tau, \tag{3}$$

where τ is the image error caused by the noise. Through this surface model, the data signal of each part of the human body is obtained, and the signal is input into BP neural network as the training sample.

2.2. Garment Data Calculation. The data signals of various parts of the human body were input into the neural network, and x_i was set as the basic sample. The physical meanings and dimensions of the data obtained are not uniform, and it is impossible to calculate them. Therefore, the samples need to be normalized [10] before the calculation, so that the data with different measurements can be uniformly processed and the final values of the data are between [0, 1] and [−1, 1]. The specific formula is as follows:

$$x_i' = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}}. \tag{4}$$

The body morphological characteristic signals after normalization are input into the hidden layer as the training signal, and the number of nodes in the hidden layer is calculated as follows:

$$j = \frac{\sqrt{n+m}}{\lambda^2} + x_i' - \log_2 \partial, \tag{5}$$

where n is the number of nodes in the input layer, m is the number of nodes in the output layer, and ∂ is the number of synapses of neurons. The output of the j node of the hidden layer is as follows:

$$G_j = \sum_{i=1} Q_{ij} x_i' + \frac{\theta_j + Q}{\log_2 \partial}. \tag{6}$$

The network weight between the input layer and the hidden layer shall be $Q = q_1, q_2, \ldots, q_m$. θ_j is the number of neurons in the hidden layer. The signal is transmitted from the hidden layer to the output layer. The number of neurons in the output layer is

$$Y_j = \sum_{j=1} G_j + \frac{\varepsilon \sqrt{n+m}}{\log_2 \partial}, \tag{7}$$

where ε is the training step. Through nonlinear dynamic calculation of the output layer signal, the activation function $f(x)$ can be expressed as follows:

$$f(x) = \frac{\varepsilon \sqrt{n+m}}{\log_2 \partial} - Y_j(\omega + \delta), \tag{8}$$

where ω is the parameter value of the upper half of the clothing design and δ is the parameter value of the lower half of the clothing design. Through weighted debugging of formula (8), the formula of network mapping force is as follows:

$$K = \frac{\varepsilon \sqrt{n+m}}{f(x) + W_1} - \sum_{r=1} W_r. \tag{9}$$

The network weight between the hidden layer and the node of the output layer shall be $W = w_1, w_2, \ldots, w_r$. In order to train the body parameter signal samples sufficiently, the dimension of the neural network samples is reduced, and the expressions are obtained as follows:

$$U = \sum_{r=1} W_r - \frac{(T+K)\log_2 \mu}{f(x) + W_1}, \tag{10}$$

where T is the error value in the process of dimensionality reduction. By constructing the data, the neural network model is as follows:

$$U = \sum_{j=1} W_j - \frac{U - \log_3 \ell}{f(x) + W_1}, \tag{11}$$

where ℓ is the training error. After many times of training, the value of the minimum node number is determined, and the number of nodes is determined to be 10. The experimental results are stable, so that the size of the network structure is established to be $12 \times 10 \times 14$. In the range of learning rate between 0.001 and 10, the optimal value of the final learning rate is determined by successive tests. Experiments show that the learning rate is set to 0.15, and the maximum number of training steps is 5000; when the sum of squares of errors is 0.001, the model achieves the best effect.

Based on the above calculation, the neural network topology of fashion design is constructed as shown in Figure 1.

In Figure 1, P_r refers to the output data. The output of the hidden layer is $Y = (y_1, y_2, \ldots, y_m)^T$.

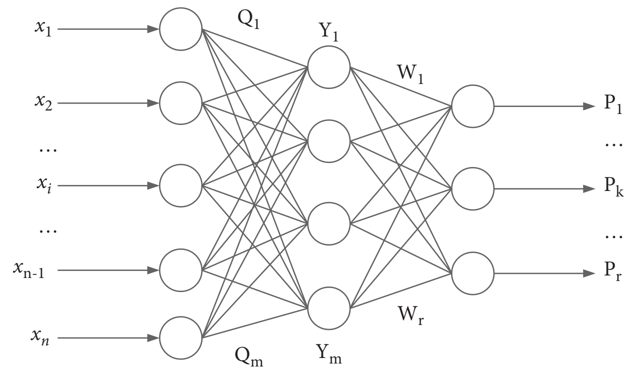

Figure 1: BP network topology diagram.

3. Management Model of Matching Degree between Human Body Shape and Fashion Design

When there is a simultaneous numerical transformation between the two variables [11–13], that is, when the correlation coefficient between the two variables is larger, then the performance stability of the obtained BP network model will decline, and the reliability of the model will be affected. In order to reduce the error of garment size data, the indexes were screened by the MIV method.

After training with sample p_i, the original indexes of BP network model increased/decreased by 12%, respectively, and the simulation test is carried out by using the obtained network structure. The result A_i is obtained, and the influence degree of each variable on the output result is calculated:

$$MIV_i = \frac{A_i - p_i}{i}. \tag{12}$$

The neural network calls the mean function in the running process of MATLAB software [14–17]. Select the appropriate variable values for constructing the neural network model. The filtering process is shown in Figure 2.

Screen waist and hip circumference and other variables, rank the results, and compose the MIV datasheet with the top 12 variables, as shown in Table 1.

From Table 1, it can be seen that the trouser length has the greatest influence on the garment pattern structure, while the hip circumference and waist circumference have the second and third place, respectively. Ankle circumference was the least influential variable, and waist length was the second. From the data in Table 1, it can be seen that ankle circumference on the garment pattern structure is negligible. Therefore, the factors of waist length and ankle girth should be removed in order to simplify the optimization procedure of the model.

The parameters are based on the selected body index data and the clothing design data from the neural network. Use the method of correlation analysis to construct the matching model:

$$V = (a_i b_i - \gamma)U + \sum_{j=1} W_j c, \tag{13}$$

where a_i refers to the morphological parameters of the upper part of the ith human body and b_i refers to the lower part of the ith human body. At this point, the matching degree model is constructed.

4. Model Simulation

The weak predictor is designed based on BP neural network model, using 5 control points as input layer and using AdaBoost algorithm to construct 10 strong predictors integrated by simple BP neural network.

The experiment selected 500 groups of human data, with 450 groups of human data randomly selected as training samples and the remaining human data selected as a test sample. The upper part of the input layer of BP neural network includes 15 parts related to it, including height, abdominal circumference, front length, back length, etc. The lower part of the input layer of BP neural network includes 10 parts related to it, including height, waist circumference, hip circumference, waist circumference, abdomen circumference, front crotch length, rear crotch length, thigh circumference, and knee height. The output layer of garment type adopts 160/84 form and chooses two values of height, chest circumference, or waist circumference according to the size style. The influence of different parts on height, chest circumference, or waist circumference was obtained accurately. Setting the output node to 1, the upper training curve is shown in Figures 3 and 4, and the lower training curve is shown in Figures 5 and 6.

It can be seen from Figure 3 that in 20 generations of training, the minimum mean square error of height prediction reaches 1×10^{-4}. As shown in Figure 4, in the 20th generation training, the minimum range of the predicted mean square error of waist circumference is $1 \times 10^{-2} \sim 1 \times 10^{-3}$. From Figure 5, the minimum value of the mean square error of height prediction after 4 generations of training is in the range of $1 \times 10^{-1} \sim 1 \times 10^{-4}$; from Figure 6, the minimum value of the mean square error of waist prediction after 6 generations of training is 1×10^{-1}.

Through the statistical analysis of the absolute value distribution of the errors of 50 test sets, it can be seen from Figure 7 that the error value of height prediction of the upper model is smaller than that of the ordinary test method, and the larger error fluctuation produced by the prediction

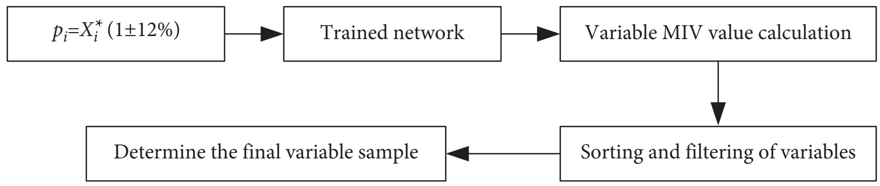

Figure 2: Diagram of MIV variable filtering process.

Table 1: MIV variable filter sort.

Number	Variable name	MIV values
1	Pant length	2.6011
2	Hips	1.9259
3	Waist circumference	0.9357
4	Inseam length	0.8534
5	Calf circumference	0.8216
6	Knee circumference	0.8122
7	Rise	0.6137
8	Waist height	0.2689
9	Thigh circumference	0.2018
10	Length of upper crotch	0.1856
11	Waist length	0.1754
12	Ankle circumference	0.0038

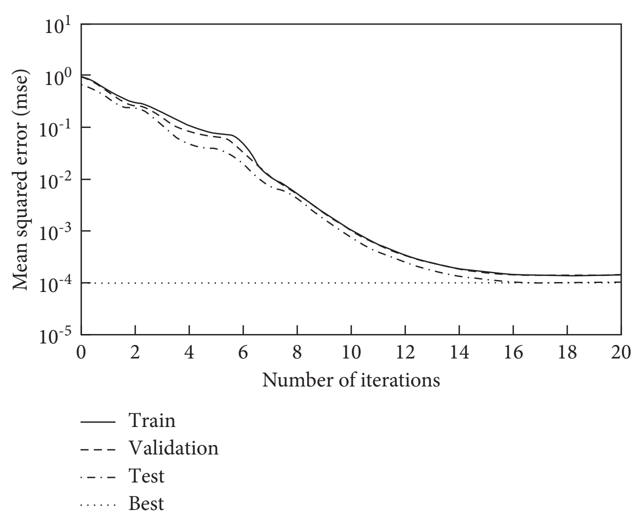

Figure 3: Training curve of height prediction model.

sample is in the acceptable range, and the overall absolute error fluctuation range of the quantitative model is less than 3%. As can be seen from Figure 8, the overall absolute error of the experimental model fluctuates slightly, less than 2%, much less than that of the ordinary model, and the range is small.

It can be seen from Figure 9 that the 50 test sets of absolute error distribution statistics in the proposed model are used for error statistics. The maximum absolute error of the ordinary model is close to 4%, while the maximum absolute error of the experimental model is only 1.6%. It proves that the experimental model is relatively stable; from Figure 10, it can be seen that the maximum absolute error of the ordinary model is slightly higher than 7%, while the maximum absolute error of the experimental model does not exceed 2%.

After the comparison of the above data, we can see that the absolute error rate of this experimental method is excellent in the coincidence degrees of predicting height with upper and lower, upper and bust, and lower and waist.

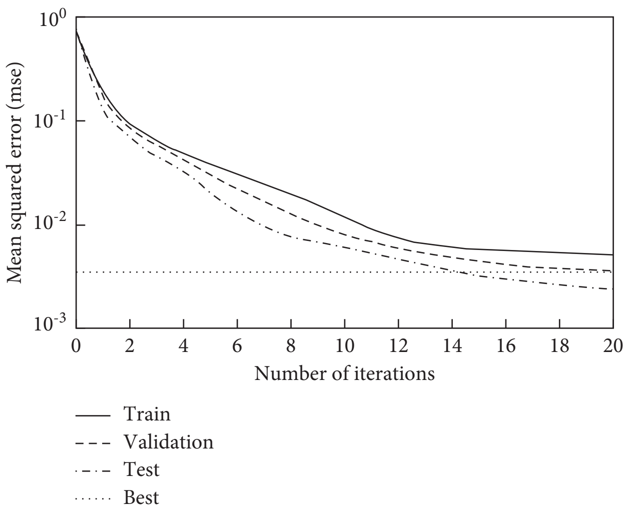

FIGURE 4: Training curve of predictive model of chest circumference.

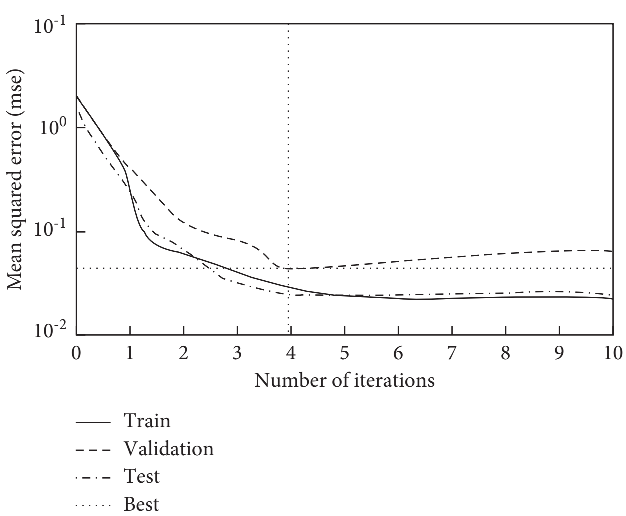

FIGURE 5: Training curve of height prediction model.

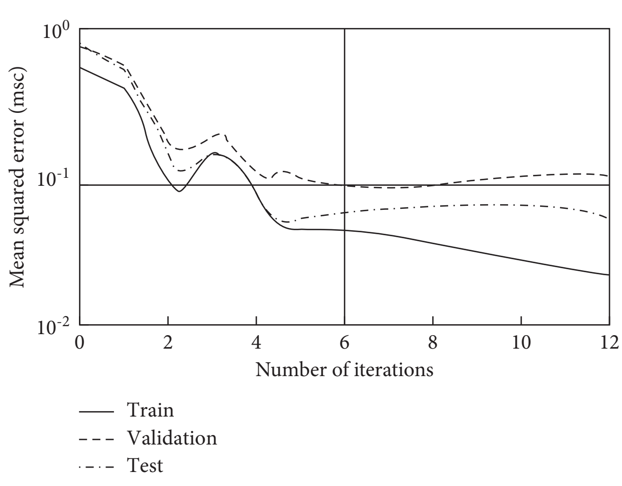

FIGURE 6: Training curve of waistline prediction model.

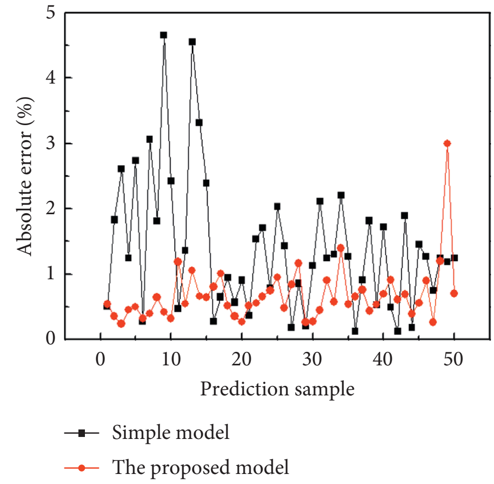

FIGURE 7: Absolute error of height prediction.

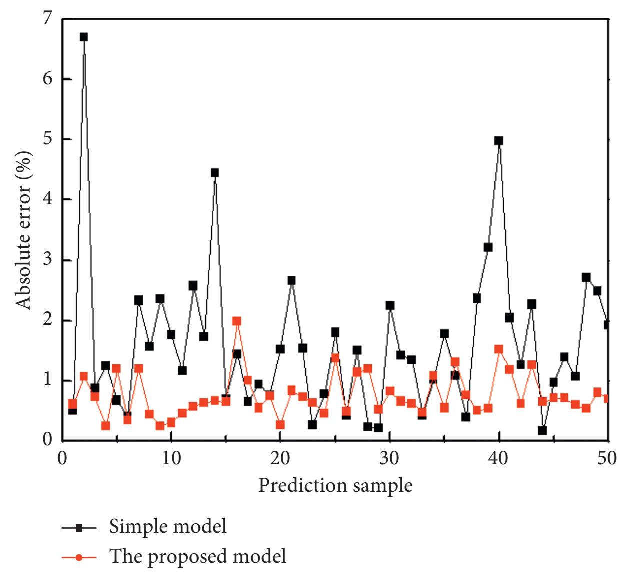

FIGURE 8: Absolute prediction error of bust size.

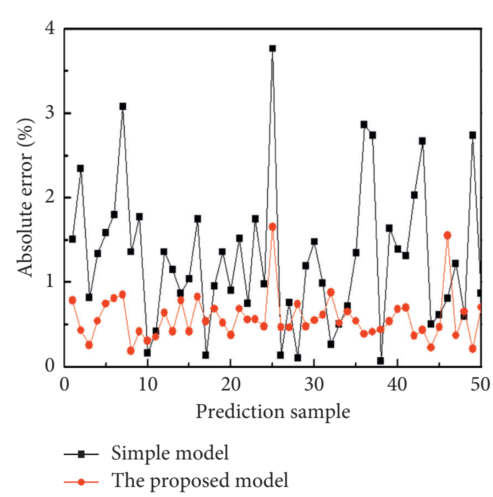

FIGURE 9: Error in height prediction.

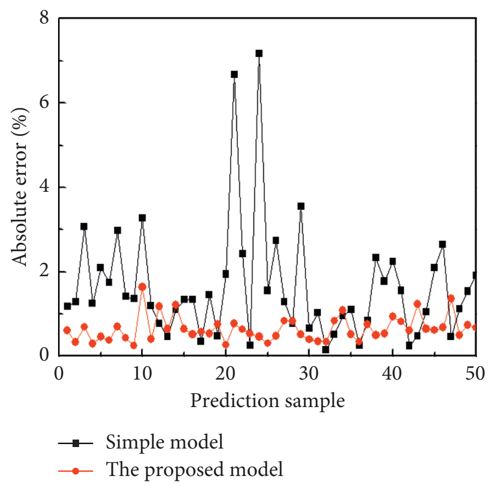

FIGURE 10: Prediction error of belts.

5. Conclusion

Based on the analysis of human body shape, this paper constructs the management model of matching degree between human body shape and fashion design. The mapping relationship between human body shape and fashion design is determined by the trial-run experiment, and the prediction model constructed by neural network is simplified by the method of selecting variables. The AdaBoost method is used to integrate 10 BP neural network classification models, and the matching degree management model of human body shape and clothing design based on neural network ensemble is constructed. The matching degree recognition precision of training set is over 95%. The modeling experience of this study shows that the shoulder width and waistline of the human body are vital in clothing design and should get more attention in follow-up studies.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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Research Article

Multipolicy Robot-Following Model Based on Reinforcement Learning

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We propose in this paper a new approach to solve the decision problem of robot-following. Different from the existing single policy model, we propose a multipolicy model, which can change the following policy in time according to the scene. The value of this paper is to obtain a multipolicy robot-following model by the self-learning method, which is used to improve the safety, efficiency, and stability of robot-following in the complex environments. Empirical investigation on a number of datasets reveals that overall, the proposed approach tends to have superior out-of-sample performance when compared to alternative robot-following decision methods. The performance of the model has been improved by about 2 times in situations where there are few obstacles and about 6 times in situations where there are lots of obstacles.

1. Introduction

Robot [1] is a topic of general interest in the automotive industry. It is a key problem that the agent attains a suitable decision of following. At present, there are two methods to solve this question, including the algorithm based on rule and the algorithm based on machine learning [2].

The algorithm based on rule, in general, makes a decision by establishing the appropriate kinematics model, so that the agent shows perfect performance in the predictable environment but may be not adjusted to the new environment. Gao et al. [3] proposed a kind of vehicle cruise system based on simulating driver method, which can safely follow the vehicle on most occasions but is hard to ensure safety and stability at the same time when it is used in complex scenes because it is governed by the driving experience of the designer. Li et al. [4] proposed a feedback control method, which has excellent following efficiency and safety performance. However, it lacks the consideration of stability in the situation of frequent speed changes.

One of the algorithms based on machine learning is based on deep learning [5] and the other is based on reinforcement learning [6]. Wang et al. [7] proposed a robot-following system based on deep neural network [8]. Compared with the traditional following model, it can adapt to complex situations better. This method, however, works by fitting the existing data, rather than generating an optimized strategy. So, it will be limited by the size of the training data set, and it sometimes fails to achieve the optimal decision in the new environment.

The algorithm based on reinforcement learning is that the agent explores continuously the environment and obtains the optimal decision by trial and error [9]. Gao et al. [10] proposed a following system based on Q-learning, which does not need a specific training set and has the ability of continuous learning. Howbeit, this method cannot respond immediately while the leading car changes its speed rapidly due to the discreteness of the algorithm. Deng et al. [11] proposed an improved DDPG algorithm. It transforms a multiobjective problem into a single objective problem by fixed weighting found by the experiment method. This method has better stability performance compared with the above methods and faster training speed compared with the traditional DDPG algorithm. However, this method finds out the real optimal weight only through a large number of simulation experiments, which is difficult to achieve in real scenes. Gao et al. gave a complete follow-up system [12] and proposed a method based on inverse reinforcement learning [13], which solves the problem that the reward function is difficult to set in the following process. Meanwhile, they conducted experiments on real scenes and verified the effectiveness of the system. Even so, he did not consider the diverse needs of robot-following decisions in different environments.

At present, the following problems still exist in the robot-following decision-making problem:

(1) It is difficult to obtain the optimal decision in different environments by the single decision-making method of robot-following
(2) It is difficult to properly weigh the relationship between various targets
(3) Most methods lack consideration of flexible targets such as robot-following stability

In order to solve the above problems, this paper proposes the multipolicy model based on reinforcement learning. This method solves the following problems such as setting reward function hardly, various users' needs, and unstable operation. It achieves the effect of surpassing the current many advanced methods in the simulation environment, basically achieves the target of safe, efficient, and stable following, and can quickly adjust the policy to deal with different environments. Empirical investigation on a number of datasets reveals that overall, compared to alternative robot-following decision methods, this method can reduce the safety risk by 66% and improve the stability performance by 6 times without affecting the robot-following efficiency when the speed of the target changes frequently. Meanwhile, the safety risk can be completely avoided, and the stability performance can be improved by 2 times when the target moves smoothly.

2. Model and Algorithm

2.1. Markova Model. Markova model is a model that the probability of the next action, which is usually used in reinforcement learning modeling, is only related to the current state, but not to the previous action and state. This model can be represented by a five-tuple (S, A, P, R, γ) [14]. S is the set of current state. A is the set of action at the next moment. P is the probability from S to A. R is the reward function. γ, ranging from 0 and 1, is the discount factor, which is used to calculate the cumulative reward value. Policy Π is the probability that the state in set S maps to every action in set $A{:}S \longrightarrow P(A)$. Provided that policy is $\pi_\theta(a, s)$, the cumulative reward value is $J(\theta) = E_{s\sim p^\pi, a\sim \pi_\theta}[\sum_{t=0}^{\infty} \gamma^t r^t]$. Reinforcement learning attains the optimal policy by maximizing.

Firstly, the robot-following process is discretized, and the sampling interval is τ. When time is recorded as t, the distance between the end-effector and the target is recorded as d_t, the relative velocity is recorded as $\triangle v_t$, the acceleration of the end-effector is recorded as a_t^2, and the state of t is recorded as s_t, $s_t(d_t, t, \triangle v_t, a_t^2) \in S$.

After getting the information of the state s_t, the end-effector outputs the action μ_t and attains the reward $R_t = f(\mu_t)$. Meanwhile, the state transforms s_t into s_{t+1}. μ_t is determined by policy Π.

2.2. Algorithm. The algorithm is a reinforcement algorithm based on the Actor-Critic structure [15]. The true Q function [16] is replaced by $Q^{\theta^Q}: S \times A \longrightarrow R$, and the target function is as [17]:

$$J(\theta^Q) = \max_{\theta^Q} E_\beta\left[\frac{1}{2}\left(r^t + \gamma Q^{\theta^Q}(s_{t+1}, a_{t+1}) - Q^{\theta^Q}(s_t, a_t)\right)^2\right], \quad (1)$$

$$J(\theta^\mu) = \max_{\theta^\mu} E_\beta\left[Q^{\theta^Q}(s_t, \mu(s_t))\right]. \quad (2)$$

The pseudocode of the algorithm is shown in Algorithm 1.

2.3. Pilot Experience Structure. Pilot experience structure is an important structure to reflect users' preferences and is also an important factor that affects the reward function.

The pilot experience structure consists of experience network and auxiliary network. Experience network is determined by the driving experience of the designer and auxiliary network is determined by users' preferences. The initial policy will be determined by the experience network and auxiliary network. The agent will generate multiple policies by adjusting the influence of the auxiliary network.

2.4. Reward Function. Reward function plays an important role in the reinforcement learning algorithm. A good reward function can accelerate the convergence of the algorithm and improve the performance of the policy. However, it may be hard to find out a good reward function when people face some problems, especially multiobjective optimization problem, in that how to balance the relationship between various targets is difficult to solve. This paper proposes a self-learning method of achieving reward function. The following will introduce the reward function of each single target and the structure of the self-learning method and multipolicy model.

2.4.1. Safety. Safety is the primary target. In general, keeping a reasonable safety distance can ensure safety performance, so the reward function of safety is defined as

$$R_1 = \begin{cases} 0, & d \geq D, \\ -1, & d \leq D, \end{cases} \quad (3)$$

Randomly initialize critic network $Q(s,a|\theta^Q)$ and actor $\mu(s|\theta^\mu)$ with weights θ^Q and θ^μ
Initialize target network Q' and μ' with weights $\theta^{Q'} \leftarrow \theta^Q$, $\theta^{\mu'} \leftarrow \theta^\mu$
Initialize replay buffer R
for episode = 1, M **do**
  Initialize a random process $\mathcal{N}$ for action exploration
  Receive initial observation state s_1
  for $t = 1$, T **do**
    Select action $a_t = \mu(s|\theta^\mu) + N_t$ according to the current policy and exploration noise
    Execute action a_t and observe reward r_t and observe new state s_{t+1}
    Store transition (s_t, a_t, r_t, s_{t+1}) in R
    Sample a random minibatch of N transitions (s_t, a_t, r_t, s_{t+1}) from R
    Set $y_i = r_i + \gamma Q'(s_{i+1}, \mu'(s_{i+1}|\theta^{\mu'})|\theta^{Q'})$
    Update critic by minimizing the loss: $L = (1/N)\sum_i (y_i - Q(s_i, a_i|\theta^Q)^2)$
    Update the actor policy using the sampled gradient:
    $\nabla_{\theta^\mu}\mu|s_i \approx (1/N)\sum_i \nabla_a Q(s,a|\theta^Q)_{|s=s_i,a=\mu(s_i)} \nabla_{\theta^\mu}\mu(s|\theta^\mu)|s_i$
    Update the target networks:
$\theta^{Q'} \leftarrow \tau\theta^Q + (1-\tau)\theta^{Q'}$
      $\theta^{\mu'} \leftarrow \tau\theta^\mu + (1-\tau)\theta^{\mu'}$
  end for
end for

Algorithm 1: The pseudocode of the algorithm.

where D is the safety distance.

2.4.2. Stability. Stability generally means that the robot should keep running smoothly at any time, and the speed should not change frequently. Therefore, the stability can be described by acceleration and acceleration change rate, so the reward function of stability is defined as

$$R_2 = \frac{1}{1+|a_t|} + \frac{1}{1+|\triangle a/\triangle t|}, \quad (4)$$

where a_t is the acceleration and $\triangle a_t/\Delta t$ is the acceleration change rate.

2.4.3. Efficiency. Efficiency mainly refers to the good co-operation between the robot and the target at any time. At the same time, if possible, the robot should maintain a high speed to ensure less time to complete the task.

Therefore, the reward function for efficiency can be defined as

$$R_3 = \begin{cases} \dfrac{v_t}{d(1+\triangle d)}, & d \geq D, \\ 0, & d < D, \end{cases} \quad (5)$$

where v_t is the current velocity, d is the relative distance, $\triangle d$ is the change of the relative distance, and D is the safety distance.

2.4.4. Self-Learning Method and Multipolicy Model. There is clearly a conflict between these targets. When the relative distance is small, the efficiency is high but there is a risk that the distance is less than the safety distance. When the speed changes small, the stability is high but the relative distance changes greatly, so the efficiency and safety are difficult to guarantee. How to determine the weight relationship between the targets is the key to integrating into a reward function. Thus, we propose the self-learning method and multipolicy model.

Firstly, several policies are given by the pilot experience structure. The agent will first use these policies for training, and at the same time, it will sample the state-action transition. After many times of training in the training environment, the user needs to give scores of every single target and a comprehensive score. The agent will convert the scores into the total reward of every training and then the reward function can be estimated according to the total reward and the distribution of state-action transition. The maximum likelihood estimation method can be used to estimate the parameter of the reward function. Likelihood function can be defined as

$$L(\mu) = \prod_{i=1}^{n} p(x_i: \mu). \quad (6)$$

Then, we can take logarithms on both sides of the likelihood function as

$$\begin{aligned} \ln L(\mu) &= \ln \prod_{i=1}^{n} p(x_i: \mu) \\ &= \sum_{i=1}^{n} \ln p(x_i: \mu). \end{aligned} \quad (7)$$

Then, we can derive the function $\ln L(\mu)$ with respect to the variable μ and make it equal to 0 as

$$\frac{d \ln L(\mu)}{d\mu} = 0. \quad (8)$$

Then, the estimated value of the parameter can be solved.

By the estimated value of the parameter μ, the probability distribution of the optimal action can be obtained. Then, the reward function can be derived from the optimal action sequence.

The agent will train a new policy from the new reward function. Similarly, the user needs to score the new policy again. If the comprehensive score is lower than before, the new policy will be added to the training data to estimate a better policy until the score of the new policy exceeds the scores of any policy before.

Since the policy function that meets the requirements is not unique, we can obtain several different value functions. In order to meet the various needs of different users for every target in the multiobjective problem, the agent will train several reward functions and policies which surpass the policies given by the pilot experience structure through the above method. Meanwhile, the agent will classify the policies according to the reward value of the subobjectives which can be calculated by the subevaluation function, which help itself choose the suitable policy in time. The subevaluation function can be attained by the subobjective reward function.

3. Experiment

To verify the validity of the model, two sets of trained policies (stability/efficiency) according to some users' needs are compared with other existing models in three different robot-following simulation scenarios.

In the following experiments, because the maximum measure distance of the distance sensor is 100 cm, we set $d_{\max}$ to 100 cm. Similarly, $v_{\max}$ is set to 55 cm/s, $a^1_{\max}$ is set to 5 cm/s^2, $a^1_{\min}$ is set to −5 cm/s^2, $a^2_{\max}$ is set to 5 cm/s^2, and $a^2_{\min}$ is set to −5 cm/s^2. Because we do not consider reversing in our experiment, $v_{\min}$ is set to 0 cm/s. In order to better observe the following state, we set τ to 0.1 ms. In order to ensure safety, we set D to 2 cm.

In general, when the distance between robot and target is less than the safe distance, we think that the state is in danger. Meanwhile, when the relative speed is equal to 0, the efficiency performance is thought of as well. Good stability performance requires that the acceleration of the robot following the target should be 0. Therefore, the average of $d - D$ and the frequency of $d < D$ can be used to evaluate the performance of safety and the StDev of $d - D$ can be used to evaluate the performance of efficiency. The average, StDev of $|\triangle v|$, and the frequency of $|\triangle v| \leq 0.1$ can also be used to evaluate the performance of efficiency. The average, StDev of $|a|$, and the frequency of $|a| = 0$ can be used to evaluate the performance of stability. Similarly, the average and StDev of $|\triangle a/\triangle t|$ can also be used to evaluate the performance of stability.

3.1. Training. The model needs to be trained first. The initial speed of the target is 0. During 0 to 30 seconds, it moves at constant acceleration which is 1 m/s^2. During 30 to 90 seconds, it moves at a constant speed. During 90 to 120 seconds, it moves at a changed speed that changes every 0.01 seconds and its value $\triangle v \sim U(-0.05, 0.05)$. After 210 seconds, the target slows down at constant acceleration, which is −0.5 m/s^2 until the velocity becomes 0. The initial relative distance is 0, and the robot starts to follow the target 3 seconds after the target starts. The change of the velocity of the target in the training scene is indicated by a solid line in Figure 1.

After training, the policy of the model is basically stable.

3.2. Testing. The method of this paper was compared with the simulation method from paper 2, Q-learning method from paper 5, and DDPG algorithm from paper 6. The performance of the models was first tested in the training scene, and the data analysis of distance, velocity, and acceleration is shown in Table 1.

In order to distinguish the various algorithms, the policy of algorithms proposed in paper 2 is called $P1$, and the policy of algorithms proposed in paper 5 is called $P2$. Similarly, the policy of algorithms proposed in paper 6 is called $P3$. $P4$ and $P5$ are the policy proposed by this paper. $P4$ tends to get higher efficiency but $P5$ prefers getting higher stability. $P4$ and $P5$ are trained by the self-learning method but do not apply the multipolicy model. $P6$ adopts the multipolicy model, and its policy set includes $P4$ and $P5$, which prefer ensuring safety and efficiency when the target changes velocity frequently and perform stability when the target moves at a constant speed.

We processed the original data to some extent and obtained the average value, standard deviation, and frequency of corresponding data. The calculation formula is as

$$\text{average: } \mu = \frac{\sum_i^n x_i}{n}, \tag{9}$$

$$\text{StDev: } \sigma = \sqrt{\frac{1}{n}\sum_i^n (x_i - \mu)^2}, \tag{10}$$

$$\text{frequency: } f(x < k)\% = \frac{\sum_n^i |k - x| + (k - x)}{2(k - x)\cdot n}. \tag{11}$$

From Table 1, compared with $P1$ to $P3$, $P4$ to $P6$ perform better according to safety. Meanwhile, $P4$ and $P6$ also ensure high efficiency. $P5$ and $P6$ have excellent stability performance.

To verify the performance of the model in different environments, the following will test the performance in two different test scenarios:

Scene 1. The initial speed of the target is 0. During 0 to 15 seconds, it moves with an acceleration of 1.5 m/s^2 + $\triangle a_{11}$, $\triangle a_1 \sim N(0, 0.5)$. During 15 to 60 seconds, it moves at a changed speed that changes every 0.01 seconds and its value $\triangle v \sim U(-0.1, 0.1)$. During 60 to 150 seconds, it moves at a changed speed that changes every 0.01 seconds and its value $\triangle v \sim U(-0.2, 0.2)$, and after 150 seconds, it moves with an acceleration of −0.5 m/s^2 until the speed is 0. The initial relative distance is 0, and the robot starts to follow the target 3 seconds after the target starts. The

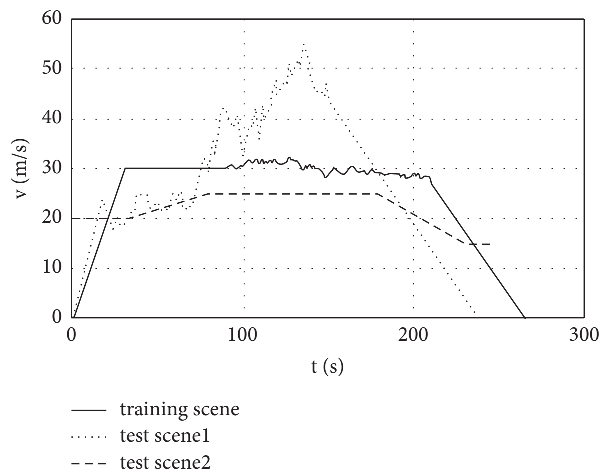


Figure 1: Velocity of the target.

Table 1: The data analysis of the models in the training scene.

		$P1^3$	$P2^{10}$	$P3^{11}$	$P4$	$P5$	$P6$
$d-D$	Average	5.00	39.78	−0.55	0.73	35.72	3.55
	StDev	5.24	34.34	1.56	4.14	49.08	5.11
	$f(d<D)$%	5.77	16.54	12.69	0.00	1.92	0.00
$\|\triangle v\|$	Average	0.65	2.97	0.11	0.08	0.39	0.15
	StDev	0.51	1.65	0.33	0.08	0.48	0.25
	$f(\triangle v \leq 0.1)$%	10.00	2.31	50.77	56.92	23.85	65.90
$\|a\|$	Average	1.18	3.01	0.38	0.34	0.27	0.32
	StDev	0.82	1.46	0.24	0.17	0.19	0.21
	$f(a=0)$%	5.00	2.69	12.31	19.23	63.08	43.68
$\|\triangle a/\triangle t\|$	Average	2.05	2.74	0.35	0.21	0.11	0.20
	StDev	1.72	1.84	0.67	0.38	0.36	0.41

*P*1 represents the policy of paper 3. *P*2 represents the policy of paper 10. *P*3 represents the policy of paper 11. *P*4 represents the policy of efficiency from this paper. *P*5 represents the policy of stability from this paper. *P*6 is an integrated model of *P*4 and *P*5.

change of the velocity of the target in scene 1 is indicated by a dashed line in Figure 1.

Scene 2. The initial speed of the target is 20 m/s. During 0 to 15 seconds, it moves at a constant speed. During 30 to 80 seconds, it moves with an acceleration of 0.1 m/s^2. During 80 to 180 seconds, it moves at a constant speed. During 180 to 230 seconds it moves with an acceleration of −0.2 m/s^2. When 230 to 250 seconds, it moves at a constant speed. The initial relative distance is 40, and the target and the robot begin to move at the same time. The speed variation of the target is indicated by a long-dashed line in Figure 1.

From Figure 1, we can find the difference between various methods. First, from the perspective of the change of the velocity of the target in the test scene, the moving speed of the target is changeable and irregular in scene 1 and the movement of the target is smooth and does not change greatly in scene 2. Obviously, the robot needs to ensure safety and improve efficiency as much as possible in scene 1. On the contrary, robots in scene 2 need not pay too much attention to the efficiency but need to improve the stability performance as much as possible.

From the results of the test scenarios on Tables 2 and 3, it is not difficult to find that *P*1 hardly keeps stable and sometimes does not leave enough distance with the target if its velocity changes fast. At the same time, *P*2 has bad stable performance and often cannot keep a safe distance with the target even if the target moves at a constant speed. *P*3 has excellent efficiency and not bad stable performance, but its poor security performance is worrying. *P*4 excessively pursues safety and efficiency without satisfactory stable performance. Similarly, *P*5 has excellent stable performance but poor efficiency. In terms of safety, efficiency, and stability, *P*6 mostly performed best in experiments.

From Figure 2, it is not difficult to find that these methods perform better in the training scene than in the testing scene, which proves that the new environment affects the performance of robot-following. Compared with other methods, the performance of *P*4, *P*5, and *P*6 is less affected. Therefore, the self-learning method has been proved to have better adaptability to the environment. At the same time, the efficiency performance of *P*6 is similar to that of *P*4, and the comfort performance of *P*6 is similar to that of *P*5, which shows that the multipolicy model can effectively improve the

Table 2: The data analysis of the models in test scene 1.

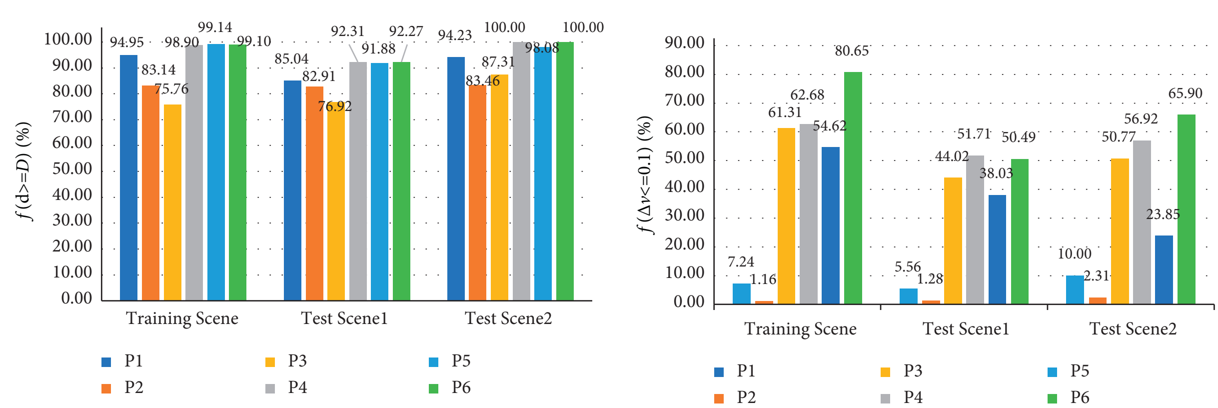
		$P1^3$	$P2^{10}$	$P3^{11}$	$P4$	$P5$	$P6$
$d-D$	Average	23.87	42.49	−0.34	3.29	38.29	3.99
	StDev	34.00	40.37	1.41	9.70	66.09	9.87
	$f(d<D)$%	14.96	17.09	23.08	7.69	8.12	7.73
$\lvert\triangle v\rvert$	Average	1.21	2.89	0.19	0.32	0.92	0.77
	StDev	1.08	1.77	0.26	0.62	1.27	0.98
	$f(\triangle v\leq 0.1)$%	5.56	1.28	44.02	51.71	38.03	50.49
$\lvert a\rvert$	Average	1.65	2.83	1.06	1.15	0.90	1.27
	StDev	1.10	1.47	0.70	0.74	0.73	0.81
	$f(a=0)$%	3.85	1.71	2.56	3.85	16.67	17.60
$\lvert\triangle a/\triangle t\rvert$	Average	2.41	2.51	1.31	1.37	0.83	0.75
	StDev	1.80	1.77	1.57	1.75	1.15	1.09

*P*1 represents the policy of paper 3. *P*2 represents the policy of paper 10. *P*3 represents the policy of paper 11. *P*4 represents the policy of efficiency from this paper. *P*5 represents the policy of stability from this paper. *P*6 is an integrated model of *P*4 and *P*5.

Table 3: The data analysis of the models in the test scene 2.

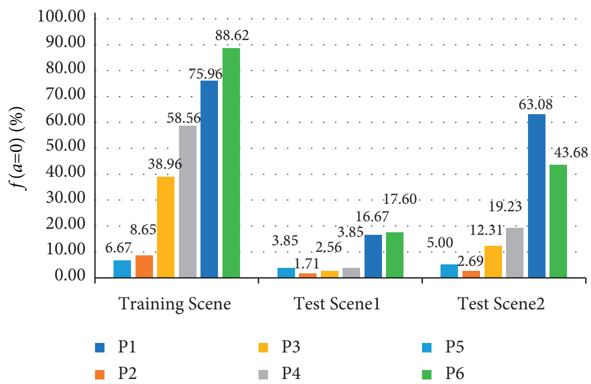
		$P1^3$	$P2^{10}$	$P3^{11}$	$P4$	$P5$	$P6$
$d-D$	Average	21.06	54.63	10.13	16.09	35.72	17.70
	StDev	77.12	77.16	53.89	73.99	105.45	71.14
	$f(d<D)$%	5.05	16.86	24.24	1.10	0.86	0.90
$\lvert\triangle v\rvert$	Average	0.92	3.24	0.28	0.37	0.58	0.36
	StDev	1.66	1.99	1.54	1.64	1.78	1.64
	$f(\triangle v\leq 0.1)$%	7.24	1.16	61.31	62.68	54.62	80.65
$\lvert a\rvert$	Average	2.56	3.21	0.72	0.53	0.35	0.23
	StDev	1.48	1.59	0.67	0.64	0.63	0.44
	$f(a=0)$%	6.67	8.65	38.96	58.56	75.96	88.62
$\lvert\triangle a/\triangle t\rvert$	Average	1.08	3.05	0.21	0.25	0.26	0.19
	StDev	0.93	1.45	0.71	0.77	0.76	0.74

*P*1 represents the policy of paper 3. *P*2 represents the policy of paper 10. *P*3 represents the policy of paper 11. *P*4 represents the policy of efficiency from this paper. *P*5 represents the policy of stability from this paper. *P*6 is an integrated model of *P*4 and *P*5.



(a) (b)

Figure 2: Continued.



(c)

FIGURE 2: Performance of various models. (a) Safety. (b) Efficiency. (c) Stability.

comprehensive performance of robot-following and better complete the following task.

To sum up, the multipolicy model overcomes the shortcoming that the traditional single-strategy model cannot adapt to different environments. By using different policies according to different environments, the multipolicy model can perfectly meet people's different requirements for different environments. Therefore, it has high practicability and the value of the study.

4. Conclusion

In this paper, a Markov decision model for the robot-following process is first modeled, then a multiobjective reinforcement learning algorithm is proposed by improving the existing reinforcement learning algorithm, and the agent could obtain a multipolicy model.

This method improves the stability performance by 6 times without affecting the robot-following efficiency when the speed of the target changes frequently and the stability performance can be improved by 2 times when the target moves smoothly.

In summary, we adopt a multipolicy model, which can take different policy preferences for different environments, so as to ensure that the optimal decision can be made in most cases. Meanwhile, we adopt the self-learning method to avoid the problem of artificial weighting, so that the robot can determine the weight ratio by itself and realize the intelligence of the robot to a greater extent. In addition, we introduce more objective considerations into the algorithm, so that the final model is a multiobjective and multipolicy agent. The contributions of this paper mainly include the following:

(1) Self-learning mode is proposed to solve the problem that the reward function is difficult to determine in the robot-following problem.

(2) The adoption of pilot experience structure reduces a large number of unnecessary explorations in the early stage of intensive learning and training.

(3) The multipolicy model can effectively improve the adaptability of the algorithm to the environment so that the decision can meet the needs of more users.

However, because the algorithm is currently only tested in simulation and real experiment has not been done yet, there are still many unknown factors influencing the actual environment. Further experiments in real environment are needed.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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Retraction

Retracted: A Quantitative Enhancement Mechanism of University Students' Employability and Entrepreneurship Based on Deep Learning in the Context of the Digital Era

Scientific Programming

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] X. Meng, G. Ren, and W. Huang, "A Quantitative Enhancement Mechanism of University Students' Employability and Entrepreneurship Based on Deep Learning in the Context of the Digital Era," *Scientific Programming*, vol. 2021, Article ID 7245465, 12 pages, 2021.

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Research Article

A Quantitative Enhancement Mechanism of University Students' Employability and Entrepreneurship Based on Deep Learning in the Context of the Digital Era

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This paper adopts a deep learning approach to analyze and study the mechanism of quantitative enhancement of college students' employment and entrepreneurial abilities in the context of the digital era. The deep learning connotation is predetermined as five abilities, which are metacognitive ability, active communication and cooperation ability, deep processing ability, creative practice ability, and learning empathy experience, and, based on this, the deep learning questionnaire is designed, and it is reclassified by exploratory factor analysis to reduce the dimensionality, and the specific indicators and scientific connotation dimensions of the deep learning questionnaire are determined; and, through the deep learning of each dimension, the problems of deep learning of college students are examined and in-depth analysis is conducted, and the inner relationship and correlation among the dimensions of deep learning of college students are derived through correlation analysis. The success of innovation and entrepreneurship depends on the innovation and entrepreneurial ability of college students, and the formation of the ability influenced various factors. Therefore, not only is studying the influencing factors of college students' innovation and entrepreneurship ability in line with the requirements of the times and social development, but also it can solve real problems. This thesis adopts a combination of two methods, qualitative research and quantitative research, to study the influencing factors of college students' innovation and entrepreneurship ability and tries to ensure the scientificity, accuracy, and comprehensiveness of the conclusion. In this paper, we analyzed the requirements of the employment prediction system for graduating secondary school students, carried out the software framework and database design of the employment analysis and prediction system for secondary school students, and designed the system modularly based on the analysis results. By applying the proposed deep feedforward neural network prediction model to the prediction system, a software system applicable to the employment prediction and guidance of secondary school students is implemented.

1. Introduction

In today's global economic system which is constantly developing and changing, whoever has the most innovative technology and the most innovative talents will have the first opportunity, and countries all over the world have launched the innovation-driven development strategy. Therefore, it is crucial to study the factors affecting the success of college students' entrepreneurship, and the ability of college students is the key that directly determines the success of their entrepreneurship, so it is crucial to study the ability of college students' entrepreneurship. As the future force of social development, the improvement of the entrepreneurial ability of college students is related to the implementation of China's innovative country construction plan and the speed of implementation [1]. Therefore, it is an effective way to solve the difficulties of entrepreneurship, the low success rate of entrepreneurship, and the pressure of social employment for college students by studying the factors influencing the entrepreneurial ability of college students and exploring the strategies to improve the it in three levels [2]. Therefore, the dataset needs to be segmented, and the model parameters are continuously adjusted through the verification set to allow the model to converge in a better direction. Not only can the improvement of college students' entrepreneurial ability improve their entrepreneurial success rate, but also the research on college students' ability can help to promote the cultivation of entrepreneurial talents and play a good role of promoting employment with entrepreneurship to drive social and economic development, enhance the country's economic strength, accelerate the construction of an innovative country, and improve the competitiveness for China in the international economic competition.

Using the method of qualitative research, through the integration, analysis, and refinement of a large amount of interview data, this paper constructs a model of the factors influencing college students' entrepreneurial ability and uses the model to discuss the factors influencing college students' entrepreneurial ability. To ensure the scientific and reasonable theoretical framework, based on the theoretical model of college students' entrepreneurial ability constructed, quantitative research on college students' entrepreneurial ability was conducted using statistical software [3]. In the research process, we make full use of the combination of qualitative and quantitative research methods, especially through in-depth interviews with college student entrepreneurs, to summarize and analyze the factors influencing the entrepreneurial ability of college student entrepreneurs and adopt questionnaire research to supplement the model of the previous qualitative research. Based on the survey data originating from the college student group, it truly reflects the influencing factors of college students' entrepreneurial ability, enriches the research theory of college students' entrepreneurial ability, and proposes entrepreneurial ability improvement strategies for the influencing factors, which provides a theoretical basis for the improvement of college students' entrepreneurial ability [4]. The employment situation of graduates from secondary colleges and universities is studied from various angles, and the problems and shortcomings of graduates in the employment process are summarized and analyzed through the analysis and tracking of the employment situation, to reflect on whether the current teaching methods and teaching priorities of secondary colleges and universities can provide students with good employment guidance and employment assistance and whether the current teaching model can cultivate excellent graduates who meet the needs of the country and society, to come up with conclusions that are conducive to adjusting the direction of career guidance and improving the quality of teaching in secondary institutions [5]. From this grid form, we can clearly see the result that these parameters can be combined. This is of far-reaching significance for the country, schools, and individuals.

The main feature of an innovative country is to realize the transformation of human resources into human capital, especially to make outstanding talents become the backbone to drive the efficient development of the economy and optimization and upgrading of industrial structure. The great demand for innovative talents in national social development has further promoted the development of innovation and entrepreneurship education in colleges and universities to cultivate and improve the innovation and entrepreneurship ability of college students, making it an important aspect of the construction of double-class universities. From the background of innovation and entrepreneurship, promoting innovation and entrepreneurship among college students is an important measure to respond to the development of new technologies and industries and to build an innovative country; from the background of the reform of entrepreneurship education in colleges and universities, cultivating entrepreneurial human capital among college students is an important path to deepen the reform of entrepreneurship education, implement the goal of quality education cultivation, realize comprehensive development of college students, and enhance social adaptability; from the background of improving national competitiveness, promoting innovation and entrepreneurship among college students is an important path to deepen the reform of entrepreneurship education, implement the goal of quality education cultivation, realize comprehensive development of college students, and enhance social adaptability. From the background of improving national competitiveness, promoting college students' innovation and entrepreneurship is an important means to give full play to the advantages of human resources and an important strategic plan to build a strong human resources country. In such a background, it is urgent to solve the problem of employment difficulties of graduates, and it has already aroused considerable concern in society. Through the analysis and refining of the initial sampling, sample selection and data mining are performed to carry out research work in a state of "theory saturation." If college students are unable to find suitable jobs after graduation and thus become unemployed, they will not be able to give full play to their strengths in various fields and add to the construction of socialist modernization. In this way, on the one hand, this will aggravate the conflicts in society, and, on the other hand, it will be a great waste of our human resources. According to incomplete statistics on the employment outlook of graduates, about 90% of school students are worried about their future employment prospects. A very important reason for this phenomenon is that college students do not receive good guidance during their school years, do not have a very clear career plan, and spend all day getting by, which eventually leads to employment failure. Therefore, early warning and guidance for school students are a proven solution to this phenomenon.

2. Current Status of Research

Neural network algorithms have made breakthroughs. A group of scientists have proposed the famous error backpropagation (BP) algorithm. The backpropagation algorithm is based on the traditional neural network algorithm, which continuously adjusts the weights and thresholds between neurons to correct the model error during the backpropagation process, significantly reducing the complexity of the model computation process [6]. The final output error of the model is reduced below an allowable threshold or terminated when the set number of training times is reached. The BP algorithm solves the nonlinear classification problem in neural network models, making a significant advance in the difficulty and scope of its use, and people once again start to focus on artificial neural networks [7]. In the research, firstly, through the unsupervised learning method, the model was trained in multiple levels, and, on this basis, the supervised backpropagation algorithm was used for parameter tuning and model correction, which successfully solved the "gradient disappearance" problem, which marked the formal introduction of the concept of "deep learning" [8]. Once deep learning was proposed, it caused a great sensation in the academic world, and world-renowned universities, represented by Stanford University, began to spend huge amounts of money and workforce on research in deep-learning-related fields. Deep learning methods have also been favored by industry, with a representative group using the deep learning model AlexNet to win the ImageNet image recognition competition. The model also took advantage of the GPU's strengths in floating-point computing, which greatly increased the speed of computing [9]. In the same year, renowned Stanford University machine learning professor Enda Wu developed a deep neural net model in conjunction with the world's leading computer experts [10]. The model extended the layers of traditional neural networks and achieved great success in the field of image recognition. Deep learning algorithms have once again attracted the attention of scholars and industry worldwide due to their superior performance.

The practice in student career guidance first began in Europe and the United States. In the United States, colleges and universities attach great importance to the employment of students, and almost all colleges and secondary schools in the United States have their career guidance organizations for all students [9]. In the UK, higher education institutions will start career guidance work for students from the moment they first enter the school and set up special career guidance files for all students in the school, so that they can carry out guidance work according to the individual students' needs so that students can be better employed [11]. According to the search results, we can see that the current career guidance in China's education is dominated by college students and higher education institutions, while information related to career guidance for students in secondary schools does not appear in the search buzzwords [12]. In addition, the search results counted subject distribution, and the distribution of the top ten subjects was obtained. From the results, higher education occupies the vast majority, followed by vocational education. This means that career guidance is also gradually gaining attention in vocational education in China, and the employment situation of students in secondary schools is getting the attention of society [13].

The purpose of this study is to predict the employment situation of secondary school graduates and provide referenceable solutions to the problems encountered by institutions in guiding students' employment. In recent years, some scholars in China have conducted relevant research on the prediction problem from different perspectives and using different algorithms. The research and application of the graduate employment prediction model using machine learning have been conducted, and, based on the research and analysis results, the hybrid feature selection algorithm with mutual information and weights (HMIGW) and XGBoost feature selection algorithm have been combined to provide an effective solution for student employment prediction, and the algorithm has been further optimized and improved based on the implementation feedback from relevant departments. The semisupervised self-training method was improved and applied to the applied research of student employment prediction in colleges and universities, combining the analysis of the prediction results of the data to be graduated students and the actual situation of students to propose guidance countermeasures, and its model has obvious advantages. The classical decision tree algorithm is used to construct a decision tree prediction model of the factors influencing students' employment, such as "whether to be employed" and "employment area," and the two models are applied to the students' employment guidance work. The natural nearest neighbor classification algorithm is used to predict the employability of college students. The model is based on the employment information input of graduates and is used to build a salary prediction model for employed college students.

3. Quantitative Analysis of Entrepreneurship Based on Deep Learning in the Context of Digital Era

3.1. Deep-Learning-Based Algorithm Design in the Context of the Digital Age. Artificial neural networks evolved from the original neuron model; inspired by biology, the learning system in the biological brain is a vast network of countless neurons, based on a topology that incorporates the basic principles of neural networks in biology, connecting many neurons to one another to process the input data [14]. In an artificial neural network, each neuron represents a specific activation function and every connection between two neurons represents a weight. In artificial neural networks, the weights and activation functions differ, and the output will be different. In order to respond to the requirements of national development for technological innovation, we need to cultivate students' corresponding innovation and entrepreneurship ability. For example, the classical algorithm in neural networks-backpropagation algorithm, based on the input layer, hidden layer, and output layer, constructs artificial neural networks, in the process of data transmission, constantly using gradient descent and adjusting the parameters, so that the error between the actual output and the desired output achieves minimum convergence and the best fit, greatly improving the robustness of data processing, and the neuron structure is shown in Figure 1.

Deep neural networks are predecessors of artificial neural networks, but, unlike artificial neural networks, they have more hidden layers. In deep neural networks, the model

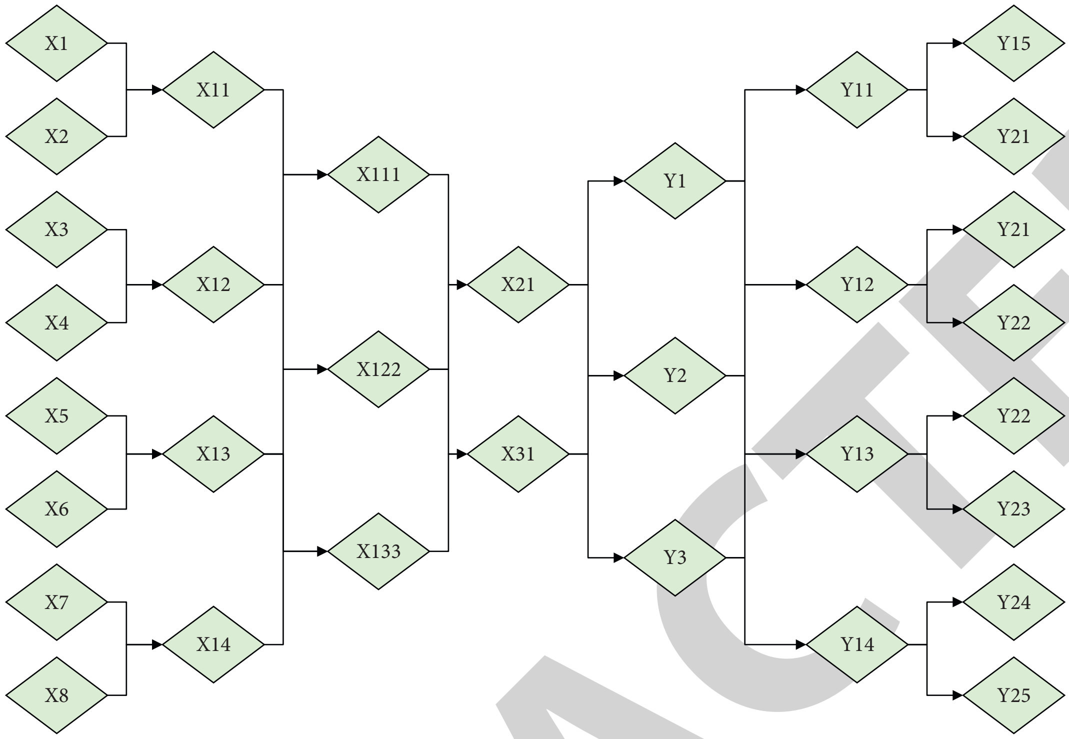

Figure 1: Deep neural network structure.

building has a strong structural feature. The interface of the network model is the input layer, which is also the entrance of the data into the model, and after the data passes through the input layer, it will enter the hidden layer, and the hidden layer is not only one layer after the data is transformed and calculated by multiple hidden layers; the result obtained is passed into the output layer and the final information is obtained. Deep feedforward neural network is a typical deep learning model whose goal is to fit some function to transform the input into some predicted output and learn the network parameters at the same time so that the model gets the optimal approximation of the function. Since there is no feedback connection to the model itself during the process from the input to the output, this model is called a feedforward model [15]. Deep feedforward networks are also composed of multiple functions compounded together, and the model is often associated with a directed acyclic graph, where the graph describes how the functions compounded and the full length of the chain is defined as the depth of the model. In practice, problems are often linearly indistinguishable and require nonlinear transformations to remap the distribution of the data, and the deep neural network itself goes through multiple levels of linear changes, with each change superimposing a nonlinear activation function, distinguishing it from a single layer of linear functions, where the multilayer network structure enables the construction of more accurate models, resulting in more powerful learning and fitting capabilities.

After building a deep feedforward neural network model, model evaluation is a key part, and the loss function defines the evaluation metric of the model when backpropagating in the network. As the name suggests, the loss function measures the difference between the predicted value of the output of the neural network and the actual value of a way to measure how good the network is, as well as by backpropagating the error to gradually improve the performance of the network on the prediction after data processing. The difficulty of optimizing the loss function varies with the parameters, the final model parameters obtained vary, and the appropriate loss parameters need to be selected for the specific problem. Common loss functions include least-squares loss function, cross-entropy loss function, and Smooth L1 loss function. In supervised learning, the loss functions we commonly use are mainly the least-squares loss function and the cross-entropy loss function.

$$L(y, f(x,\theta))\frac{1}{4}(y + f(x,\theta))^2. \tag{1}$$

The multiclassification cross-entropy loss function is an extension of the binary classification, with the following equation:

$$H\left(y^i, y^j\right) = \sum_{i,j=1}^{Q} y_i \ln\, y_j. \tag{2}$$

After determining the loss function, the model has all the functional structures to perform data processing and the next step is to determine the optimization algorithm for the model when performing backpropagation. The optimization algorithms for deep learning are stochastic gradient descent methods. In the gradient descent method, again, there are different forms of operations. The batch gradient descent method iterates through the entire sample of the network model to update the weights of the network, which greatly increases the number of operations on the network data and reduces the speed of backpropagation of network errors. The more professional and in-depth related abilities that need to be possessed in the later development period and maturity period are not the focus of training at this stage. The innovative and entrepreneurial abilities that should be possessed in the awakening stage should be generally oriented to all college students, with emphasis on innovation spirit, learning ability, entrepreneurial personality, and so forth; and the innovative and entrepreneurial abilities that should be possessed in the initial stage are mainly aimed at the transformation of scientific and technological achievements and practicality. In contrast, the stochastic gradient descent method will only iterate through one of the samples of the network model input samples to update the weights, which will increase the speed of the network to reduce the amount of computation, but because the iterations use too little data, this often leads to a decrease in the accuracy of the network model, which makes the result be a local optimal solution, but it cannot get the global optimal solution.

Dropout is a random strategy in the training process of a deep model, that is, dropping a neuron node in a neural network at random with a certain probability. Since the dropout method acts on a different small batch of training data each time, each time a random part of neurons is dropped can be seen as a retraining process of the neural network, resulting in a completely different network structure [16]. Dropout is compared to the Bagging method, which is traditionally used for large-scale deep neural network training methods due to its involvement of the overall model and data; when the size of the network is large, this integration method not only takes a lot of computational time but also consumes a lot of data storage space. Therefore, the Bagging method does not have a great advantage when training small batches of data. Dropout, as a lightweight alternative to Bagging, can achieve the good properties of the Bagging method on small batches of data, that is, to achieve exponential numbers of neural networks for training and evaluation.

$$Z_k = \frac{\exp\left(x_k\right)}{\sum_{i=1}^{k} \exp\left(x_k\right)}. \tag{3}$$

To apply deep neural networks for employment prediction, the computational process based on deep neural networks is given in Figure 2. The main processes are as follows: first, the dataset is preprocessed and all types of features are transformed into numerical features using one-hot coding; second, the dataset is divided into a training set and a test set in the ratio of 7 : 3, and the deep neural network is trained using the feature data from the training set and the training results are verified using the test set to find the best combination of parameters using a grid search method.

The definition of evaluation metrics is important for the evaluation of a network model and is an important factor in validating the quality of the network model; in this paper, accuracy, recall, and F1 value are selected as the evaluation metrics of the network model. For the categories, the formula is as follows:

$$\begin{aligned} p_c &= \frac{\mathrm{TP}}{\mathrm{TP\text{-}FP}}, \\ R_c &= \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN\text{-}1}}, \\ F_c &= \frac{1 - \beta^2 - p_c + R_c}{\beta^2 - R_c}. \end{aligned} \tag{4}$$

In deep learning, the data needs to be sliced and normalized for training and testing. The dataset is divided into the training set, validation set, and test set; the training set is used to train the model, the validation set is used to observe the model performance, and the test set is used to verify the model effectiveness. The model obtained from the training set alone does not prove that the prediction model is effective and may reduce the usefulness of the model due to overfitting, so the dataset needs to be sliced and the model parameters are continuously adjusted through the validation set so that the model converges towards a better direction. First, the dataset needs to be split into two parts: the training set and the test set. Nowadays, there are two popular methods of data partitioning: one is that 80% of the data is used for training and 20% of the data is used for testing, and the other is that 70% of the data is used for training and 30% of the data is used for testing. To better test the generalization ability of the model, the second method is chosen. 30% of the data is divided into the test set, which is not trained for model parameters and is only used as the final test evaluation of the model. Meanwhile, for the first 70% of the data, 10% is randomly selected as the validation set, which will act as a test evaluation within the training for each training of the model, while the remaining 60% or so of the data is the data that is trained for the parameters. They are 0.443 and 0.387, respectively. Among the three-level indicators, initiative spirit, reform willingness, and abiding by the contract have larger weights, indicating that they are more important to the spirit of innovation; in the evaluation of the various elements of innovation and entrepreneurship ability, the ability to transform results has the highest weight.

$$K\left(x_1, x_2\right) = \exp\left(\gamma\left(x_1 - x_2\right)\right)^2. \tag{5}$$

The method of lattice search belongs to the classical exhaustive search method from the mathematical essence. In this paper, all the possible values of the parameters of the network model are combined in a specific permutation, and after they are combined, the result of the permutation is presented in the form of a grid, from which we can see the results that can be combined into these parameters [17]. Then all the parameters in the formed grid can be combined in a way to feed the network model, and then the whole network model will be trained, the performance of the network model will be continuously evaluated, and the performance parameters after each evaluation will be compared so that the best combination of parameters can be continuously filtered.

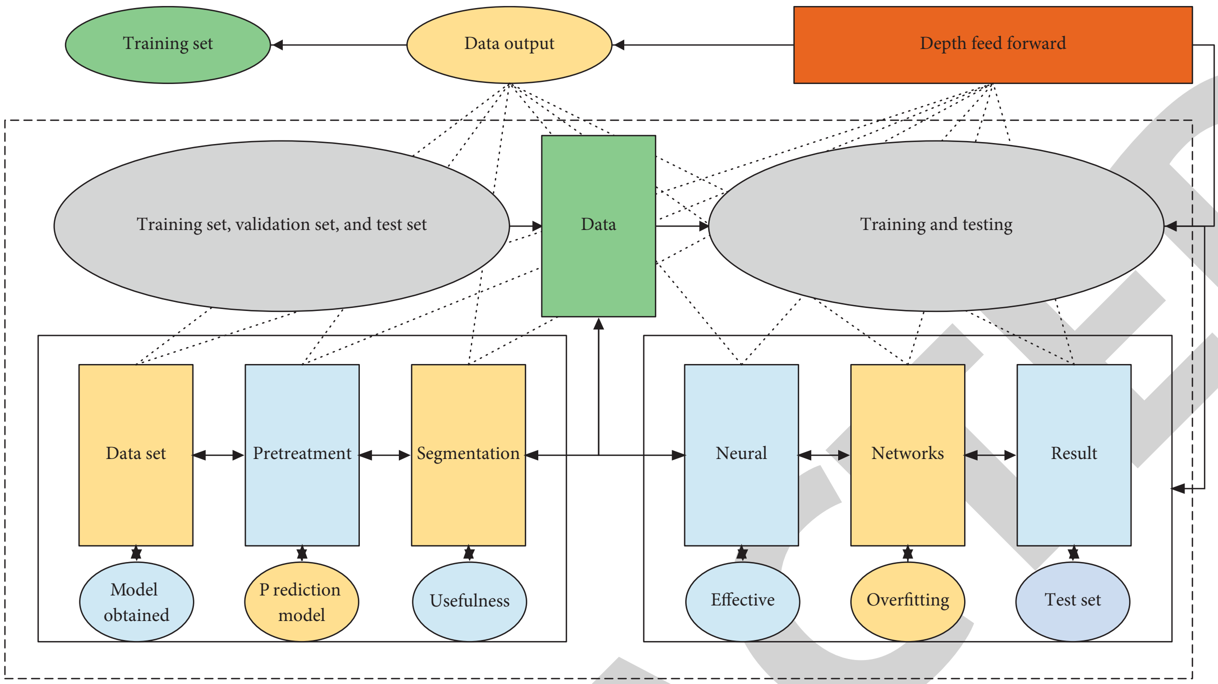

Figure 2: Computational flow based on deep feedforward neural network.

3.2. Quantitative Design of University Students' Employability and Entrepreneurship. The theory and practice of statistics tell us that the connotation of everything comes from its essential properties, and the revelation of its essential properties comes from the data and information mining that portray its appearance [18]. Therefore, in the face of such a complex research topic as the qualitative study of the factors influencing college students' entrepreneurial ability, the key to achieving the purpose of the study is the way to collect data and to reprocess the data on this basis to obtain the most reliable information. Considering the limitations and timeliness of secondary data, according to the principle of "the best performance to price ratio" and focusing on the qualitative indicators that can best describe the factors influencing college students' entrepreneurial ability, we adopted a combination of theoretical sampling and interviewing and carried out sample selection and data mining through the analysis and refinement of the initial sample. The study was carried out in a state of "theoretical saturation" through sample selection and data mining. The optimal sample size is the smallest amount of data saturated with the highest level of content required to achieve the research objectives [14]. According to the requirements and operation procedures of in-depth interviews, to ensure the representativeness of the data, we first determined the sampling frame of regions, taking into account the concentration of college students' entrepreneurial bases and the number of entrepreneurs, through existing records and fieldwork, and then further determined the sampling frame of survey members, requiring that those who can be used as sample members must have at least one successful experience of entrepreneurship during their school years or within two years of graduation.

In this way, they can provide more convincing information, such as the initial intention of starting a business, the confusion of starting a business, what are the main factors affecting the business, what abilities are needed in the process of starting a business, and what kind of environment is more favorable for starting a business. According to the number of entrepreneurs and the current situation of entrepreneurship, stratified random sampling is adopted to draw a sample of 30 people from each area in the sampling area box, respectively; then interviews are conducted, the order of interviews is determined by drawing lots, the interviews start from number one, and if the interviewer can no longer provide new information they will be eliminated; to define the concept of the innovative entrepreneurial ability of college students, we cannot ignore the special characteristics of the college student group, so that its concept is different from the general concept of innovative entrepreneurial ability. The abovementioned method will be an effective way to solve the difficulties of college students in the aspects of starting a business, reducing success rate of starting a business and the pressure of social employment. To define the concept of innovation and entrepreneurship among university students, it is necessary to differentiate the concept from the general concept of innovation and entrepreneurship and to narrow down the scope and make it more specific and relevant. Unlike the entrepreneurs and start-ups studied in the past, the entrepreneurship of university students advocated by the state is not just as simple as "setting up a stall" or "doing a small business."

It should be an innovative and valuable venture. Therefore, based on the existing literature research and the characteristics of our society and college students, we define the concept of college students' innovative entrepreneurial ability as follows: the ability of college students to create and improve new things and transform them into economic, social, and cultural values that are beneficial to personal or social development by using their scientific and cultural knowledge and surrounding resources, which is mostly reflected in the innovative entrepreneurial primary stage, as shown in Figure 3.

At the critical period of accelerating the construction of an innovative country, great importance is attached to the cultivation of innovative talents and university students, as highly sophisticated talents who master scientific and cultural knowledge and advanced technology are the main force to achieve this grand strategic goal. Therefore, in the context of "mass entrepreneurship and innovation," the innovation and entrepreneurship ability of college students should actively respond to the theme of the times and reflect the characteristics of the new era. Therefore, the modernity of the innovation and entrepreneurship ability of college students refers to the fact that college students closely combine their ideal beliefs and life pursuits with national development and social progress, respond to the development requirements of national science and technology innovation, knowledge innovation, and system innovation, as well as strategic opportunities, focus on new technologies, new business modes, and new models, and take the initiative to accumulate and improve or cultivate the corresponding innovation and entrepreneurship ability with external support. This model is used to discuss the influencing factors of college students' entrepreneurial ability. To ensure that the theoretical framework is scientific and reasonable, based on constructing a theoretical model of college students' entrepreneurial ability, statistical software is used to conduct quantitative research on college students' entrepreneurial ability. The new round of business innovation and technological change is reshaping the global economic landscape, and countries all over the world are emphasizing the importance of innovation, but, due to the different social systems, different degrees of development, and different development processes in each country, the requirements for the innovation and entrepreneurship capabilities of college students also vary, and each country should develop corresponding specific strategies in line with national realities and development needs.

The innovation and entrepreneurship capabilities that need to be possessed or focused on by innovation and entrepreneurship subjects are different for each stage. Unlike other innovative entrepreneurial groups in society, such as entrepreneurs and migrant workers, the time frame for this particular group of university students is mainly limited to the period during which they attend university and within two years of graduation, and the corresponding entrepreneurial stage is the awakening of consciousness and the start-up phase, which focuses more on the innovative spirit, learning ability, and the knowledge and skills required for the start-up phase [19]. The more specialized and in-depth competencies required in the later development and maturity stages are not the focus of this stage. The innovation and entrepreneurial ability that should be possessed in the awakening stage should be generally oriented to all college students, focusing on the innovation spirit, learning ability, and entrepreneurial personality, while the innovation and entrepreneurial ability that should be possessed in the start-up stage mainly targets a small group of people who transform scientific and technological achievements and start a business, focusing on enterprise management ability and so forth, as shown in Figure 4.

The data obtained through survey research in quantitative research is the basis for scientific decision-making, and the selection of appropriate data analysis methods and data analysis software is an effective means to ensure scientific decision-making. According to the research needs and research questions, this paper will use descriptive statistical analysis, factor analysis, hierarchical analysis (AHP), principal component analysis (PCA), and full weight method to determine the weights of innovation and entrepreneurship education ecosystem composition indicators of research universities. Among them, the main methods used in the weight analysis were hierarchical analysis (AHP), principal component analysis (PCA), and the full weight method. In the specific data processing, statistical analysis software programs such as SPSS and AMOS were used as the main analytical tools for data analysis. The specific statistical analysis steps are as follows: Firstly, the research group distributed the questionnaire of "the composition index of innovation and entrepreneurship education ecosystem in research universities" to each university, the subjects were teachers and students, and the survey data were recorded into electronic files. Aiming at the influencing factors, a strategy to improve entrepreneurial ability was proposed, which provided a theoretical basis for the improvement of college students' entrepreneurial ability. Secondly, according to the questionnaire responses, incomplete responses, regular responses, short responses, and self-contradictory responses were eliminated, and valid questionnaires were obtained. Again, using SPSS statistical software, the obtained data were processed, and descriptive statistical analysis, exploratory factor analysis, and validation factor analysis were conducted on the questionnaire to determine that the questionnaire had good reliability. Finally, the combination of hierarchical analysis, principal component analysis, and full weight method was used to determine the weights of the composition indicators of the innovation and entrepreneurship education ecosystem of research universities to help managers better determine the focus of their work.

4. Analysis of Results

4.1. Deep Learning Algorithm-Based Results in the Context of the Digital Age. The method of lattice search belongs to the classical exhaustive search method from the mathematical essence. In this paper, all the possible values of the parameters of the network model are combined in a specific permutation, and after they are combined, the result of the permutation is presented in the form of a grid, from which we can see the results that can be combined into these parameters. Then all the parameters in the formed grid can be fed into the network model in the way of combination, and then the whole network model will be trained, the

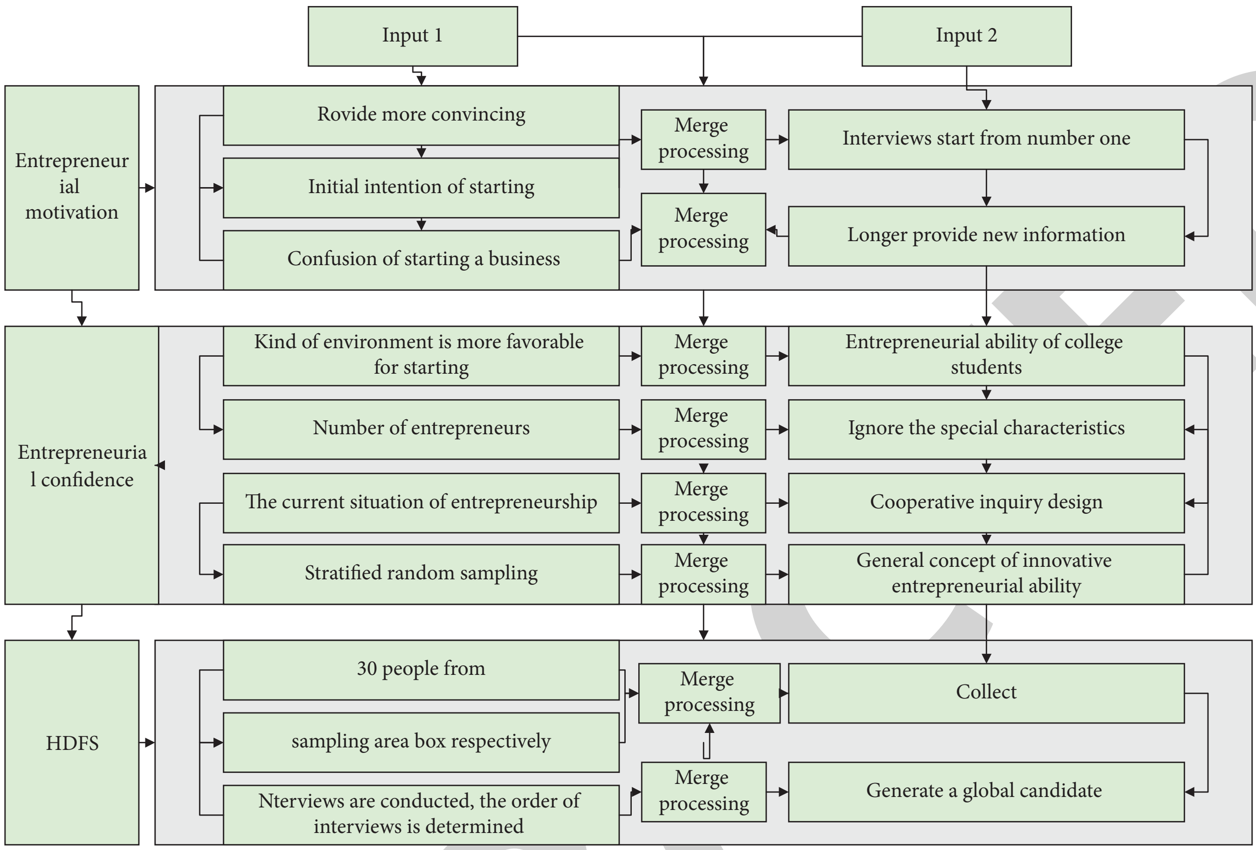

Figure 3: Hypothetical model diagram.

performance of the network model will be continuously evaluated, and the performance parameters after each evaluation will be compared so that the best combination of parameters can be continuously filtered. In the model proposed in this paper, the most important parameters are the number of training sessions, the number of batches, the number of hidden layer neurons, and the step size. Based on practical experience, the benchmark parameters in grid search are determined: the number of training times is 400, the number of batch processes is 20, the number of neurons in the first hidden layer is 16, the number of neurons in the second hidden layer is 8, and the step length is 0.001. Applying deep feedforward neural network for employment classification of secondary school graduates, Figure 5 gives the classification accuracy, loss function with iteration for the training and testing process of student employment dataset, and change curve with the number of iterations. From Figure 5, the accuracy of the training set of the student employment dataset rises rapidly in the oscillation until 20 iterations, and then the oscillation of the training set decreases until it stabilizes after 250 iterations; the test set rises rapidly until 15 iterations and then rises slowly and stabilizes. As can be seen from Figure 5, the training set loss decreases rapidly in oscillation until 250 iterations and then gradually stabilizes; the test set loss decreases rapidly until 300 iterations and then slowly decreases and stabilizes.

Recently, the gradient boosting decision tree model has been performing very well in commercial applications and is a good example of the concept of learning from mistakes. Gradient boosting decision tree is an iterative decision tree algorithm that consists of multiple decision trees and the conclusions of all the trees are accumulated to make the final answer. The obtained results can be used as an important measure to guide the construction of an innovative country; from the background of college entrepreneurship education reform, cultivating college students' entrepreneurial human capital is an important path to deepen entrepreneurship education reform, implement quality education training goals, achieve comprehensive development of college students, and enhance social adaptability. It was a more generalizable algorithm along with SVM when it was first proposed. The basic idea is to train the newly added weak classifiers based on the negative gradient information of the current model loss function and then combine the trained weak classifiers into the existing model in an accumulative form, and, in each iteration of the computation, the negative gradient is calculated with the current model sample as the goal to train the weak classifiers for merging. The final computed weights are used for the model update. In the experiments, the gradient boosting decision tree model is trained in the training set using XGBClassifier in XGBoost and then a grid search is performed in Scikit-Learn using Research on the estimates of the specified parameters, and all hyperparameters are tested to find the best combination to produce the best results as shown in Figure 6.

In machine learning, support vector machines (SVMs and support vector networks) are supervised learning

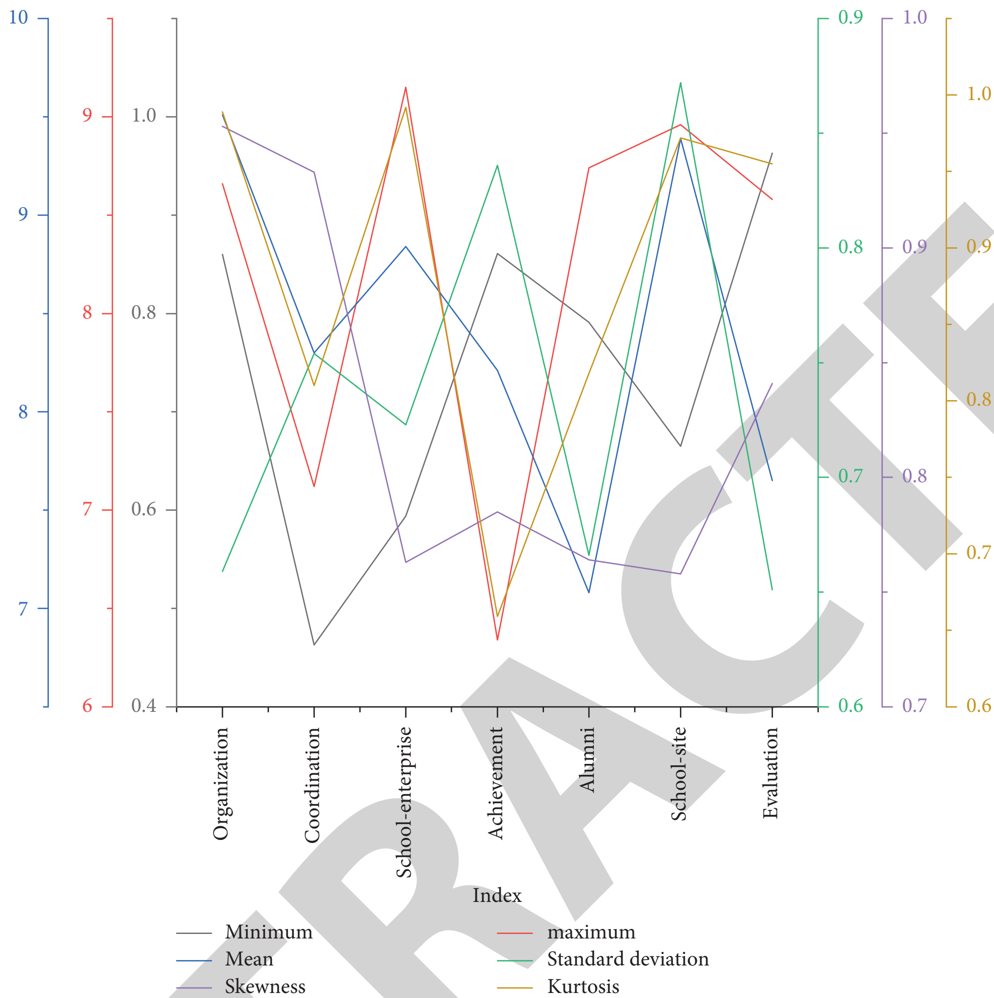

Figure 4: Descriptive statistics of organizational mechanisms.

models associated with relevant learning algorithms that analyze data and identify patterns for classification and regression analysis. Support vector machines are used to distinguish between various types by finding a hyperplane in a multidimensional space. This hyperplane is determined by the support vector. In the experiments, the support vector machine model is trained in the training set using SVM. Then a grid search is performed in Scikit-Learn using research on the estimates of the specified parameters and all hyperparameters are tested to find the best combination to produce the best results. In this paper, the classical cross-validation method is used to calculate the prediction accuracy of four different models. By comparison, it demonstrated that the deep feedforward neural network model used in this paper has better accuracy than the traditional algorithm. The results prove that the employment prediction algorithm for secondary school graduates based on deep neural networks outperforms other employment prediction algorithms in terms of accuracy, recall, F1 value, and training speed, proving that algorithms based on the current state-of-the-art deep learning have better prediction results compared to traditional machine learning algorithms and finally evaluating the algorithms used in this paper.

4.2. Quantitative Results of University Students' Employability and Entrepreneurship. The results of the evaluation of the degree of importance of the elements of entrepreneurial human capital indicators of university students show that in the structure of entrepreneurial human capital indicators of university students the weight of entrepreneurial consciousness is 0.312, the weight of innovative spirit is 0.198, and the weight of innovative entrepreneurial ability is 0.49. The innovative entrepreneurial ability has the highest weight and is the most important, and the weight and importance of entrepreneurial consciousness and innovative spirit are second to innovative entrepreneurial ability. This is highly consistent with the objective requirement of entrepreneurial activities for practical skills. The weight and importance of entrepreneurial consciousness are second only to innovation and entrepreneurial ability, which indicates the high importance of entrepreneurial consciousness to the cultivation of entrepreneurial human capital among college students. Gradient descent is continuously used to adjust parameters, so that the error between the actual output and the expected output reaches the minimum convergence, and the degree of fit is the best, which greatly improves the robustness of data processing. The weight and importance of innovation spirit

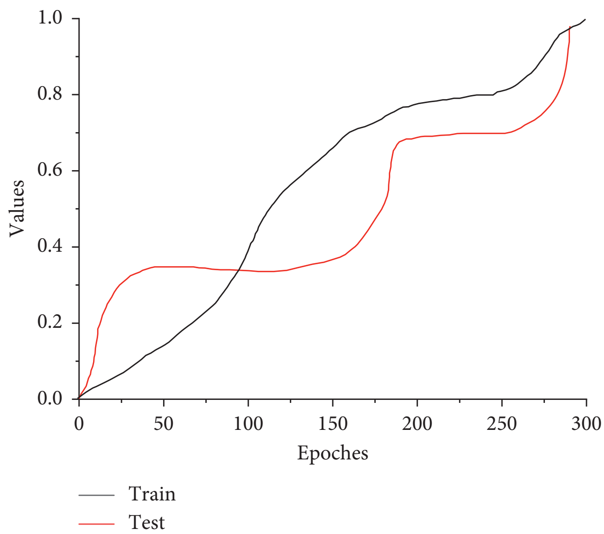

Figure 5: Training set and test set accuracy.

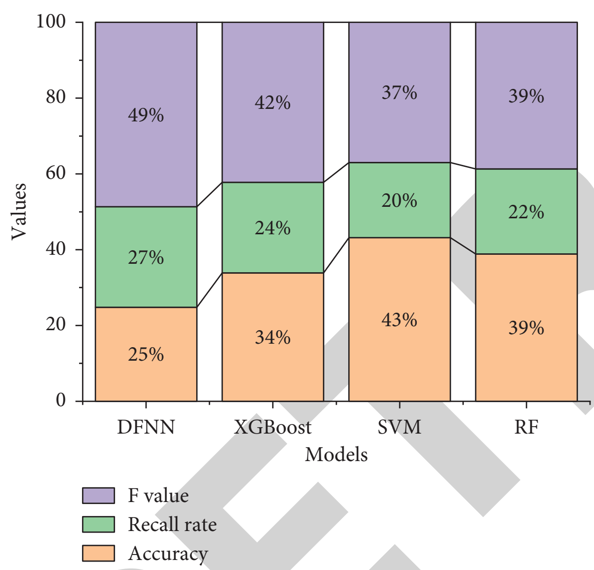

Figure 6: Comparison of prediction results of deep feedforward neural network model with other models.

are lower than innovation and entrepreneurial ability and entrepreneurial consciousness, which may be because innovation spirit is a more implicit and potential characteristic among human capital characteristics and is less visible compared with innovation and entrepreneurial ability and entrepreneurial consciousness, resulting in the relatively low perception of its importance among survey respondents, as shown in Figure 7.

In the evaluation of the elements of entrepreneurial consciousness, the weights of entrepreneurial motivation and entrepreneurial confidence are both 0.5, and the weight of each three-level indicator is the same, which indicates that entrepreneurial motivation and entrepreneurial confidence are equally important to entrepreneurial consciousness. In the evaluation of the elements of innovation and entrepreneurship, the weight of the ability to transform results is the highest, and the weights of innovative thinking, knowledge production ability, and technology transformation ability in the three-level indicators are higher and more important. In addition, the weight of innovation ability is second only to the result transformation ability, while the weight of business management ability is relatively low. The analysis may be due to the lack of experience in entrepreneurship and insufficient enterprise management ability among entrepreneurial college students in research universities in China, which causes the survey respondents to pay insufficient attention to business management ability.

The fuzzy comprehensive evaluation method is a comprehensive evaluation method based on fuzzy mathematics. This comprehensive evaluation method converts qualitative evaluation into quantitative evaluation according to the affiliation theory of fuzzy mathematics; that is, it uses fuzzy mathematics to make an overall evaluation of things or objects that are subject to multiple factors. It has the characteristics of clear and systematic results, can better solve the fuzzy and difficult to quantify problems, and is suitable for various nondeterministic problems. The empirical evaluation of the level of the entrepreneurial human capital of college students is mainly based on the sample data obtained from the questionnaire survey, and the fuzzy comprehensive evaluation method is used to evaluate the current situation of the level of the entrepreneurial human capital of college students in research universities. The overall level of the entrepreneurial human capital of college students in research universities is measured by the results of the scores of three first-level indicators of entrepreneurial consciousness, innovation spirit, and innovation and entrepreneurial ability, as shown in Figure 8.

From the overall score of the evaluation index of the entrepreneurial human capital of college students, the overall level of the evaluation index of the entrepreneurial human capital of college students is good (75.68 points). Among them, innovation and entrepreneurial ability and innovation spirit are at a good level, and entrepreneurial consciousness is relatively low and at a passing level. According to the weight distribution of the evaluation, innovation and entrepreneurial ability have the highest weight and the most prominent importance, followed by entrepreneurial consciousness. The speed of back propagation of network errors is reduced. When the stochastic gradient descent method is iterating, only one sample of the network model input samples will be iterated to update the weight, although this will increase the running speed of the network and reduce the amount of calculation. The results of the comprehensive evaluation of the model show that the innovation and entrepreneurship ability, which has a higher weight, has the highest score (79.82 points), which is close to the excellent level. This indicates that the special group of college students in research-oriented universities has a higher quality of innovation and entrepreneurship ability; the requirements and training objectives of research-oriented universities for students' innovation and entrepreneurship ability are more systematic and professional than other forms of education, and they also put forward more

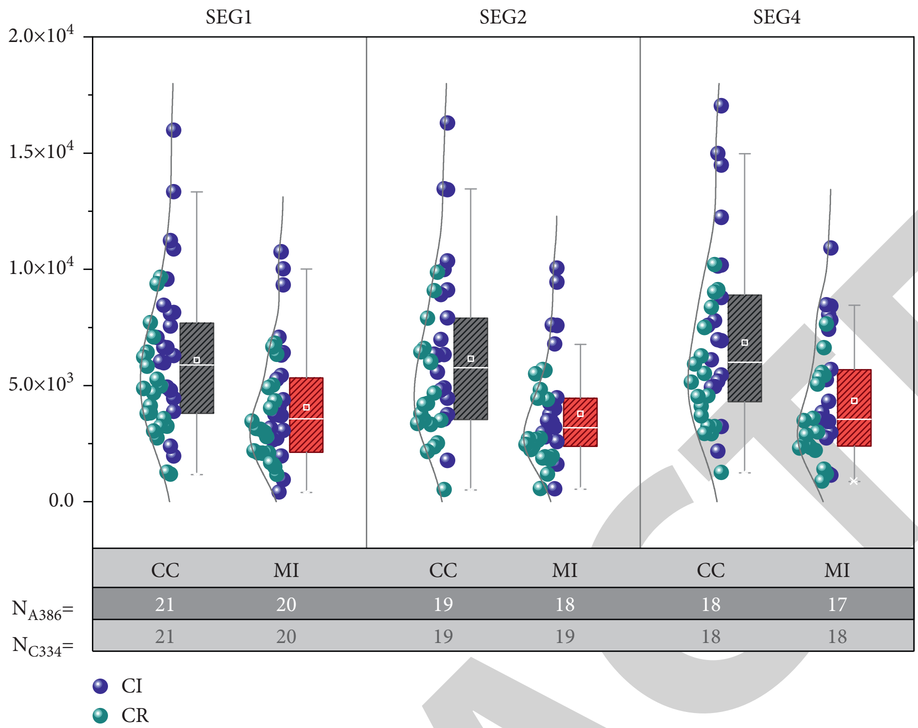

FIGURE 7: Comparison of secondary indicators to which innovation and entrepreneurship belong.

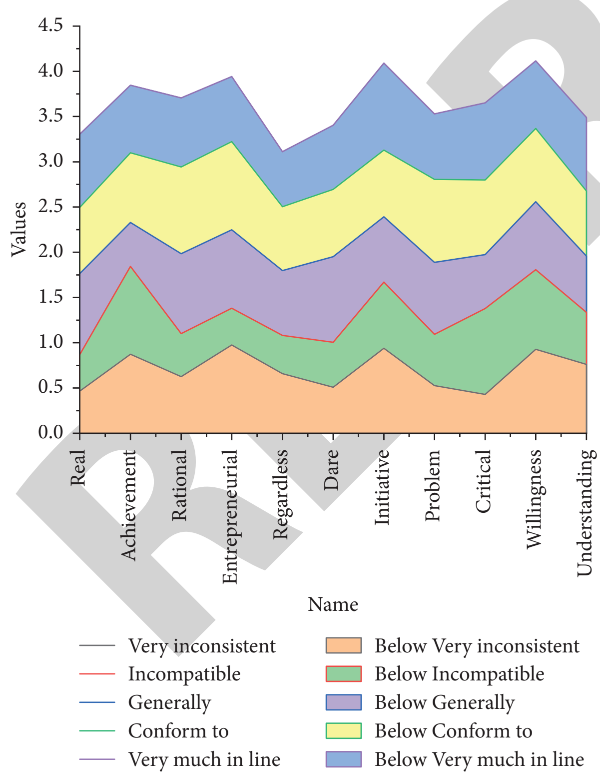

FIGURE 8: Quantitative indicator judgments.

strict requirements on the three core elements of innovation and entrepreneurship knowledge, innovation and entrepreneurship ability, and innovation and entrepreneurship quality. Through the combination of the three elements, the requirements for students' entrepreneurial ability and entrepreneurial quality are formed, and then entrepreneurial standards are formed. For research universities, it is to cultivate research-oriented entrepreneurial talents with innovative consciousness and creativity. Creativity is expressed in the creative thinking, creative knowledge, and creative ability of research university students in the entrepreneurial process, and innovation is expressed in the innovative spirit, entrepreneurial consciousness, and creative personality in the entrepreneurial process.

5. Conclusion

Based on the constructed evaluation indexes of the entrepreneurial human capital of college students in research universities, the overall level of the entrepreneurial human capital of college students in research universities was measured empirically through a fuzzy comprehensive evaluation. To theoretically explore the inner mechanism of entrepreneurial ability generation among college students, the research hypothesis that there is a positive correlation effect between professional ability and entrepreneurial human capital among college students in research universities is proposed and verified by structural equation modeling. The results of the model showed a significant positive correlation between professional competence and entrepreneurial human capital among college students in research universities. In response to the characteristics of data features exhibiting high dimensionality, the sparse connection between features and features, no centralized distribution, and complex and diverse feature attributes, among which discrete features are predominant and continuous features

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Research Article

The Construction of a Digital Resource Library of English for Higher Education Based on a Cloud Platform

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This paper conducts in-depth research and analysis on the construction of an English digital resource library for higher education through the cloud platform. The cloud platform allows the English resource library to achieve integration, efficiency, scalability, and interactivity and then solves the problems of how to realize the co-construction and sharing of resources among multiple platforms in vocational institutions and improve the utilization rate of resources. The construction of the English resource library in higher vocational institutions cannot be separated from the collaboration between institutions and enterprises, and institutions must face up to the problems existing in the construction of the current resource library. Firstly, the requirements of various aspects of the higher vocational English digital resource library system are given from three aspects, functional requirements, performance requirements, and operational requirements, in strict accordance with the requirement analysis steps; secondly, the overall technical architecture and network topology architecture of the education cloud platform where the higher vocational English digital resource library system is located are analyzed and given in general to ensure the security, scalability, and ease of operation of this platform and then the resource collection and resource storage. The application of cloud computing technology can solve the problems of difficulty in obtaining teaching resources, insufficient storage space, limited communication, and slow circulation; it can realize the integration and integrated management of various resources through technologies such as networking, virtualization, and distributed storage. Finally, based on the optimization strategies proposed in this paper, the core modules of the higher vocational English digital resource library system are designed and implemented, and some important and representative interfaces and source codes are demonstrated. To ensure the operation performance, the situation of multiple users operating the higher-level English digital resource library system at the same time is simulated, and the overall performance of the higher-level English digital resource library system is evaluated for the common operations such as uploading resource files, downloading resource files, and querying resource files, which confirms the rationality of the design strategy in this paper and greatly improves the user experience and increases the utilization rate of teaching resources.

1. Introduction

With the development of modern science and technology, "informatization" is strongly advocated in all occupations, and the education industry is no exception, and the rapid development of information technology has provided great convenience to the education industry. In recent years, the emergence of various information-based teaching methods such as flipped classrooms, catechism, mobile classrooms, virtual learning communities, and collaborative laboratories have injected new vitality into modern vocational education and provided various channels for students to learn independently. The traditional classroom is no longer the main source of knowledge acquisition for students [1]. The teaching mode of self-learning before class, internalizing during class, and improving after class has become one of the most advocated teaching modes for English teaching in higher education institutions. However, due to the lack of sufficient teaching resources, it is often extremely difficult to implement this teaching model in practice, and its effect is not satisfactory. The use of cloud computing technology can solve the problems of difficult access to teaching resources, insufficient storage space, limited dissemination, and slow circulation; it can realize the integration and integrated management of various resources through networking, virtualization, distributed storage, and other technologies [2]. Using the cloud platform (i.e., cloud computing platform), we can easily realize the integration and utilization of resources, improve the efficiency of resource acquisition, and reduce the cost of resource storage management. Therefore, the establishment of a cloud-based higher vocational English teaching resource library is the most crucial step to solve the current bottleneck problem of higher vocational English teaching [3]. Teachers need to push learning resources to students before, during, and after class, while traditional higher vocational English digital resources have the characteristics of complex, scattered, disorderly, and incomplete content, and they also lack fragmentation suitable for mobile learning. Along with the forward movement of students' learning, the construction of ubiquitous and fragmented digital resources for mobile learning is increasing on the agenda. Traditional high-quality course resources do not have the characteristics of openness and sharing and are not suitable for mobile learning because of their complicated contents [4]. There are more studies on the construction of university English resources, but fewer studies on the construction of higher vocational English resources, and higher vocational students have their own practical and vocational characteristics. The traditional research on the content of higher vocational English resource construction based on cloud platforms is not comprehensive enough, such as the construction of students' independent learning resource library and the construction of a resource library for listening and speaking ability development which involve less content.

Using cloud computing to create an information platform for educational resources, a multitenant model is implemented with the help of SOA, SaaS, and network storage computing, which can be used by various educational institutions or other organizations for training and other purposes. With the distributed and parallel computing technology of cloud computing, the corresponding speed of servers is greatly increased [5]. The platform implements unified management of data, security, and applications in the "cloud" so that users only need to focus on their own business and do not need to spend more time on management. This mode greatly saves the investment of education information technology, changes the way the government invests in education, and will get more economical and better practical results and improve economic efficiency. It changes the obsolete way of learning for students, allowing them to choose their preferred personalized page form and style, select applications and resources on-demand, and integrate their learning, work, and life on this education cloud platform, greatly improving learning efficiency [6]. With the help of the education cloud platform, students can be provided with customized services to meet their different learning needs and learning styles and provide personalized learning support services such as learning tools so that students can develop lifelong learning using the education cloud platform, thus improving the overall education level for the establishment of a lifelong education system. Higher education students are not highly self-aware and do not develop the habit of searching English learning resources from the internet for a long time, much less spending a lot of energy to find learning materials. It is not only in line with the students' existing learning style but also can reduce the difficulty of searching for learning resources and strengthen their interest in English learning. Users only need to focus on their own business without spending more time on management. This mode greatly saves the investment in education informatization, changes the way the government invests in education, and will achieve more economical and better practical results. From the point of view of the development of teaching informatization, with the strong support and advocacy of the education department, the informatization infrastructure of vocational colleges has become more perfect, which has largely promoted the teaching reform, and the introduction of the blended learning model has brought vitality to the informatization process of higher vocational English. However, the lack of teaching resources has become a barrier to this process, and the lack of resources to support the implementation of the new teaching model has affected the final presentation effect Thus, the use of cloud technology to build English teaching resources in higher education is a part of the informatization process that cannot be ignored.

The necessity of establishing a resource bank for higher vocational English can be analyzed from both internal and external aspects: "internal" mainly refers to the change of students' learning style, and "external" mainly refers to the promotion of the information technology education process The internal and external changes and developments have put forward new requirements for learning resources and teaching resources, which make it urgent to establish a resource base for higher vocational English teaching. First, from the perspective of students' learning mode transformation, in the background of network development, students can search learning resources from the internet, and they are used to get the corresponding English learning materials from the internet platform. Cloud computing for higher education is an internet-based cluster service group, which is an easily scalable, user-targeted, and virtualized resource. The construction of a teaching library based on a cloud platform can improve the overall digital management level, deepen teaching reform, improve teaching quality, reduce the cost of software and hardware equipment, improve the utilization rate of resources, achieve maximum resource sharing, and solve the problem of uneven and insufficient resources. Under the teaching system, the analysis of resource data, timely replenishment of various types of tense and scarce resources, and understanding the user learning process propose the most suitable user learning methods and content to achieve push and trigger learning. The teaching resource base based on the cloud platform incorporates teaching resources from all over the world, which is rich in resources and easy to expand, and the platform automatically analyzes the data of the resource base at this stage so that the data of the resource base can be expanded in time according to it to better meet the needs of users. And the platform also recommends excellent learning materials and learning methods according to each user's situation to realize push and trigger learning.

2. Current Status of Research

Modeling user profiles and their integration with the retrieval process is an effective way to develop personalized information retrieval within educational digital repositories [7]. Therefore, it gradually raises the question about the dynamic development of this profile for the resource retrievers to set up queries. Slimani et al. also focused on this issue, and eventually, they proposed two models for personalized search based on digital educational resources. The first approach is to build an index of repository resources, and the second approach is to build user profiles and facilitate their development after each query is submitted by the user based on a classical Bayesian network (a probabilistic graphical model) representing the search activity. This model is used to meet the user's personalized information retrieval needs [8]. Bedenlier et al. focused on the ARIADNE project, supported by the European Commission; the project's goal is to facilitate the sharing and reuse of digital educational resources [9]. To achieve this, a Europe-wide repository of educational resources, called the Knowledge Pool System (KPS), has been created. They found that a key feature of the KPS is the underlying metadata specification, which has been used in a wide range of experiments [10]. This, in turn, is the basis for the emerging metadata standard for learning objects developed by the IEEE Learning Technologies Standards Committee. In their article, they, therefore, focus on the analysis of the metadata model of the ARIADNE project and discuss the ARIADNE tools developed to support metadata authoring, database querying, and course development activities. On the contrary, reliable adaptive systems, which require adaptation strategies and key characteristics of students, will help to automatically change the educational environment. Thus, they introduced an adaptive platform whose constituent parts are personal data, psychological characteristics, and special educational needs. And it can customize the delivery of digital educational resources provided through a database using the specific characteristics of the student. In addition to this, the platform has some adaptations in the user interface to meet the needs in special education.

However, there is a lack of understanding of students' attitudes and competencies regarding the use of digital educational resources in professional learning in the relevant studies [11]. Therefore, Xu analyzed the competencies that students should have in using digital educational resources which include understanding the requirements of using digital educational resources in professional learning and understanding the methods of using digital educational resources in professional learning. Then, he used the experimental method to establish a model of students' ability to use digital educational resources in professional learning and made an experimental demonstration of the validity of the model [12]. With this, he hopes that the process of professional training suitable for students can be optimized, and the use of digital educational resources can be increased. A collection of tags created individually by different users is called a mass taxonomy, and the motivation of such users to tag may have an impact on the data description of the resource [13].

In his study, the focus is on how user motivation to tag resources can affect educational resource creators in terms of resource design. Then, based on the study, methods are proposed to identify the motivations of different types of users as well as to reduce the impact of such user motivations on the metadata of digital educational resources. Finally, it is concluded that a universal resource model is designed to match user motivations, thus more closely matching the individual needs of users. It is reflected in learning through the digital education resource library to make changes in user motivation to explore the resource development model that is more suitable for user needs. The content should be practical, concise, and convenient for mobile learning. Teachers should fully consider the students' English foundation and the actual needs of mobile learning when building an online resource library for higher vocational English. The complex knowledge is miniaturized to facilitate students' mobile learning so that learning can happen anytime and anywhere, thus meeting learners' needs for practicality.

3. Analysis of the Digital Resource Library Construction of English for Higher Education on the Cloud Platform

3.1. Analysis of Digital Repositories on Cloud Platforms. With the development of internet technology, the storage and analysis of big data are imminent, and the resources of colleges and universities have also increased dramatically with the popularity of teaching; the traditional teaching resource platform data cannot meet the requirements of big data storage of various resources due to excessive maintenance costs [14]. It is urgent to migrate the resource data of traditional storage methods to the big data platform and unify the storage and management to provide a rich, user-centered, cloud-based teaching resource library for every teacher and student in colleges and universities [15]. The overall level of education is improved for the establishment of a lifelong education system. Higher vocational students have low self-consciousness, have not developed the habit of searching for English learning resources from the internet for a long time, and will not spend a lot of energy looking for learning materials. Figuratively speaking, the resource library is a bridge built between various available resource servers at the bottom and the application and analysis of resources, thus realizing the migration of teaching resources on-demand, storage management, common construction and sharing, access on-demand, resource analysis, and resource recommendation, comprehensively improving the utilization of resources and increasing the mutual collaboration between teachers and students.

Given the maturity of the internet and the Hadoop distributed storage technology, the server side of this university teaching resource library adopts the Hadoop-based distributed big data storage architecture, and the client side adopts the B/S architecture [16]. The repository provides functions such as accessing various teaching resources from the internet by different users according to their needs, online learning by teachers and students, recommendation of various resources of interest by the system according to the characteristics of the users, resource data migration from traditional resource data platforms, analysis of resource data, management, and monitoring of resource data. The number of file IO accesses should be minimized, which can greatly ease the pressure on the user's synchronous access server and improve the performance of the Hadoop file server. Considered comprehensively, Linux operating system should be used. When storing massive file data, the metadata of the file will generally reach hundreds of *G*, or even reach the TB level, so that it is difficult to load into memory at one time, and on comprehensive consideration, the system uses the HBase distributed database to store the metadata of the file and the absolute address of the file and to create a unique index from it.

When multiple users access concurrently, the client often has relatively low access efficiency, which can be detrimental to the client experience if the access time is too long. This repository should meet the access time efficiency of the client when concurrently accessing large files, but after all, Hadoop is a distributed storage and computing platform developed based on Java, which often has great limitations on the storage and access of a large amount of small data. The system needs to be designed based on the existing small file merging scheme to facilitate both the read operation of small files and the write operation of small files so that the read files and write files can cooperate and do their best to meet the storage, access, and analysis of all kinds of resource data by most teachers and students.

This system provides cloud storage services in the B/S mode, in the server cluster, the web server runs the HUFFS API application, while the database server consists of MySQL and HUFFS cluster server. The client users are connected to the router and switch through the internet so that they can access the Hadoop cluster and get the resources and data in the corresponding cluster as shown in Figure 1.

Various teaching resources contain rich and practical educational information. The teaching resources in this resource library refer to various media materials, online courses, common examination questions, high-quality courseware, and classic cases that have digital form and can provide substantial help to various users in learning, teaching, and research and optimize education-related business processes through various resources. This resource library is required to be built with the participation of people from all occupations to establish its resource-rich, resource-worthy, and substantially helpful resource library [17]. Various users collect various teaching resources through various daily methods, then submit requests for storage resources via HTTP through the terminal client, and finally transmit them to the Hadoop cluster using the TCP connection after forwarding by the web server and then transmit and store teaching resources. To a large extent, it has promoted the teaching reform and the introduction of the mixed learning model, which has brought vitality to the process of higher vocational English informatization. With the participation of many users, this repository will become increasingly rich. However, with the construction of this repository, the number of daily users will increase, and concurrent uploads and storage of various resources will occur from time to time. The response to the request sent to the web server will become very slow due to the load pressure on the web server and will cause the web service to crash, which will seriously affect the user experience. To this end, a message queue-based web server clustering strategy is proposed to optimize the teaching resource request process.

While building this repository, the resources in the old repository are collected after a long time of maintenance and management, and if they are discarded when building this repository, it will cause a great waste of resources. In this paper, we examine the migration of teaching resource data and design and implement a migration of the old repository's resource data to this repository's Hadoop cluster while minimizing the impact on the repository's normal operation, in order to lower the repository's construction costs and increase resource utilization, as shown in Figure 2.

One of the reasons for the construction of this resource library is that the construction of the old teaching resource system is not standardized, the classification of resources is unclear, there is a lack of unified standards, the content is redundant and messy, which is extremely inconvenient for teachers to access various teaching resources and for students to conduct independent learning according to their situation, and brings a lot of inconvenience to the management personnel for the management of various resources; secondly, various teaching resources are reconstructed, resulting in the poor utilization of a large number of storage devices. The cost of maintenance gradually increases in the later period, which brings a certain economic burden to the schools. For the consideration of repository construction cost, avoiding duplicate construction, and improving the utilization rate of existing resources, it is necessary to migrate various teaching resources to this Hadoop repository data platform by using data transfer, data copy, or data migration technology through the business function of this repository to reduce the input cost and improve the utilization rate of resources. Three factors need to be considered in the design of this repository for the migration of teaching resources. Migrating resources intend to reduce costs and avoid duplication of construction, and if the cost of migrating resources is higher than the expected cost, then there is no point in migrating resources. Resource data migration must ensure that the business can be used normally, so it is necessary to choose the least online users late at night. When the data are migrated, the integrity of the data needs to be ensured, and the loss of all kinds of important data cannot be caused by sudden power failure or human intervention. The client adopts the B/S system architecture. The resource library provides different users with

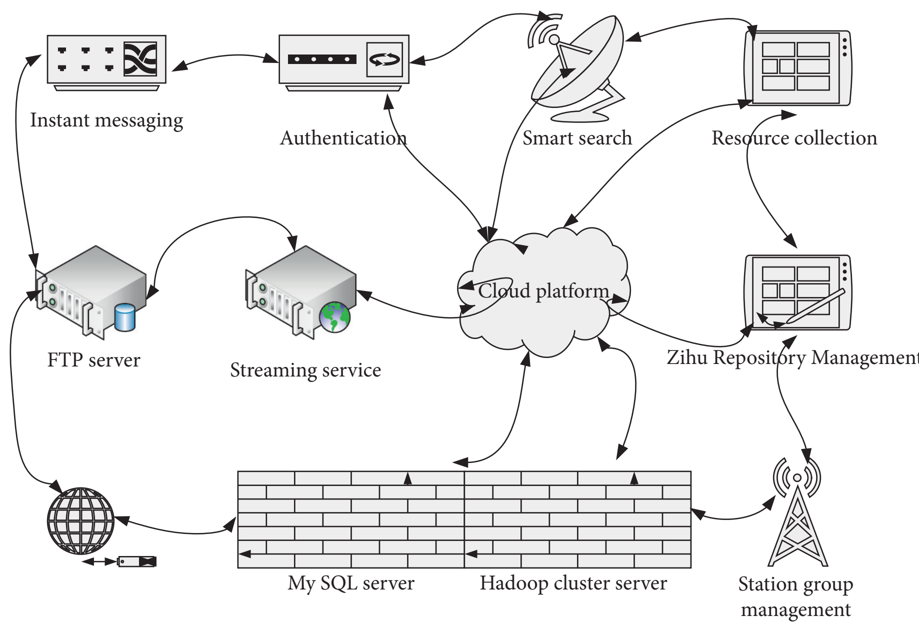

FIGURE 1: Overall technical architecture of the cloud service platform.

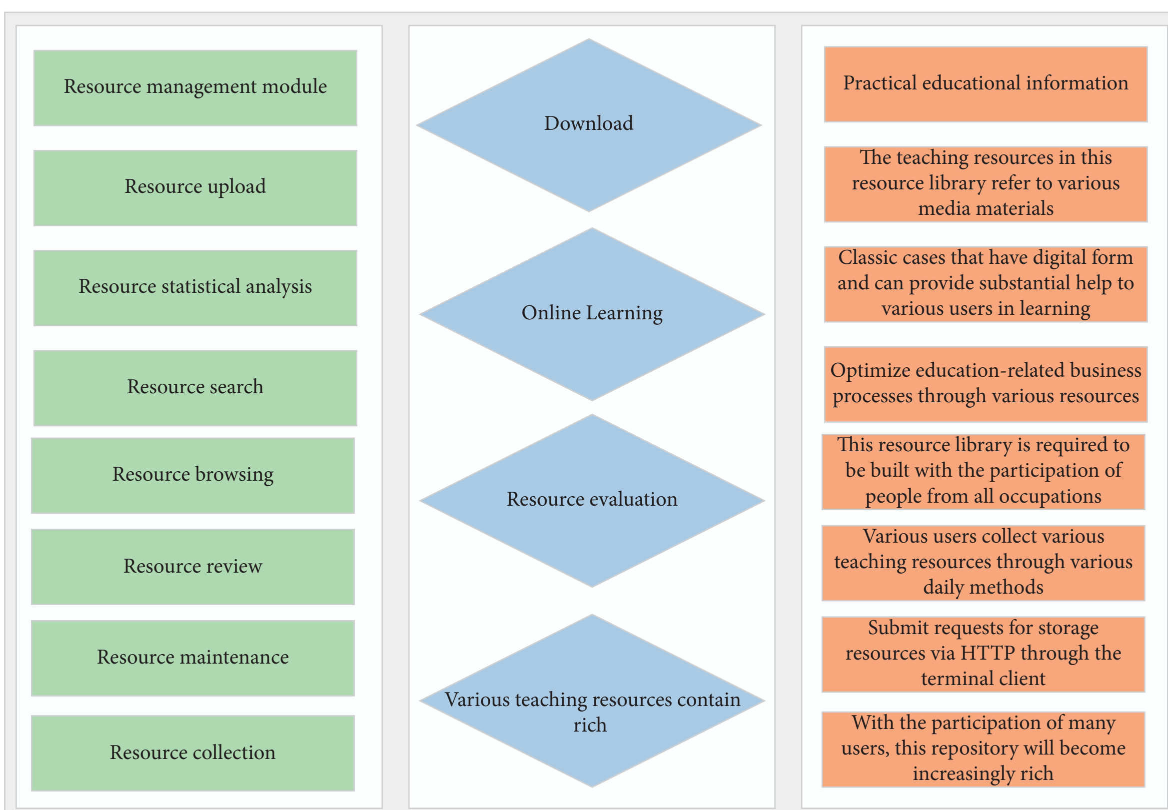

FIGURE 2: Functional diagram of the resource management module.

various teaching resources from the internet according to their needs and online learning for teachers and students, and the system recommends various resources of interest according to the characteristics of users and a traditional resource data platform.

There are numerous methods of data migration techniques, which have been summarized as structured data migration and unstructured data migration. Structured data migration refers to the migration of structured data from relational databases into nonrelational databases through various suitable methods. Unstructured data migration generally refers to copying or moving resource files to a Hadoop cluster in some way. The main methods for unstructured data migration are direct replication copy, data mirroring migration, database built-in tools, etc. The following is a detailed design of structured data migration and unstructured data migration.

3.2. Performance Analysis of the English Digital Resource Library for Higher Education. The module should have the complete management right of the whole system function, with the authority to manage the basic data of the system and manage other users. The system administrator has the highest authority and is responsible for the maintenance and management of the whole system functions and has the authority to access the database directly and is responsible for the parameter setting of the whole system, which includes user management, permission management, file storage path management, announcement management, and database management. The system administrator is not involved in the maintenance of the repository, so he only has the authority to browse the resource information [18]. The resource manager is mainly responsible for the maintenance of the resource library, which includes uploading resources, downloading resources, browsing resources, retrieving resources, approving resources, and other functions. The resource manager can modify or delete the resources when reviewing them, so the position it holds is very important and can be said to be the core part of the whole system. Teachers are the most beneficial group in the resource management system, not only can they browse and download all the resources in the system but also can upload resources to share with other teachers. Teachers have the functions of personal information modification, resource browsing, resource retrieval, resource uploading, resource downloading, resource evaluation, etc. After logging into the system, teachers can browse the resources in the system and download the resources they are interested in to help organize their teaching; at the same time, teachers can also upload their resources to the teachers' private resource library, and if they want to share the resources, they need to apply to the resource manager as public resources and wait for approval before other users can use them. Students are the most used group in the teaching resource library and have the functions of resource browsing, resource searching, resource downloading, and resource evaluation. Students can log in to the system, browse all the resources in the system, and download the resources they are interested in, which provides convenience for learning after school. Students can also retrieve the information in the resource library and search for the information they want to browse. Students can also evaluate the resources and interact with other users while browsing them, as shown in Figure 3.

The statistical analysis function provides school leaders and network administrators with statistics about the resource library for decision-making reference use [19]. There are often great restrictions on the storage and access of a large amount of small data. The system needs to design a set of convenient small file reading operations based on the existing small file merging scheme. The items of statistical analysis include resource uploads, usage, resource access ranking, resource depletion, and statistics on the classification of the resource library and the total number of resources. In resource uploads, we can know the total number of resources uploaded, the number of resources to be reviewed, the number of resources deleted, and the number of users involved in uploads, and we can also see the statistical analysis data of each user's resource uploads. In the resource usage statistics, we can see how many registered users the resource library has, the total number of clicks on the resources, and the total number of favorites created by the users.

This function realizes the user and resource as the center and provides personalized resource recommendation service according to user behavior data. The service object of this function is the user, and the recommendation object is the resource, which solves the problem that it is difficult for the user to choose the resource. This function first classifies the uploaded resources according to the content of the resources to get the resource topic relationship and then forms the resource topic model; then, the system establishes the user personalized interest relationship based on the interest preference information registered during user registration and the daily collected user operation behavior data and then establishes the user personalized interest model Finally, based on the previously generated resource topic model and the user personalized interest model, the relationship between the user and the resource is generated, and a user recommendation model is established to recommend several resources to the user that the user has not acted recently.

The design and implementation of the user personalized interest model for this feature relies on user behavior data, and a wide variety of user behavior data is generated in this feature. Table 1 shows the user behavior data required for this feature. From the data in the table, some behaviors were generated by student and teacher operations, while some behaviors can be generated by all users (including visitors). In terms of data size, the data size of resource online browsing, resource access time, and search resources is the largest, while the data of resource welcome, favorite resources, unfavorite resources, resource comments, and other behaviors can only be generated by registered users (e.g., students and teachers), and these behaviors are of medium size; for downloading resources, resource exposure behaviors can only be generated by a small percentage of registered users authorized by the administrator These behaviors are of moderate size. From the point of view of real-time access, behavioral data such as resource access time, resource welcome, favorite resources, unfavorite resources, resource comments, and download resources need to be accessed in real time. Some behaviors, such as clicking on a resource to view it and searching for it, do not require real-time access.

This feature is mainly to associate users and resources and then make recommendations for resources. And there are 3 main methods to associate between them: user and resource, user and user, and user and resource feature. User-resource means the user is directly associated with a

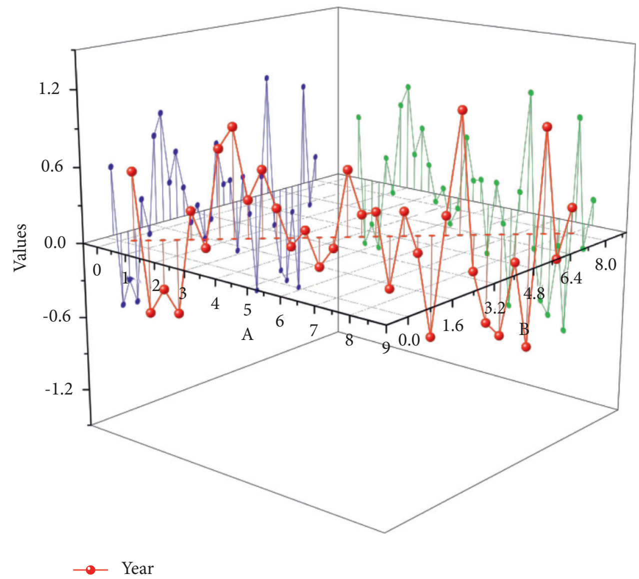

Figure 3: Average number of daily user visits to the platform.

Table 1: Structure of resource relationship data table.

Description	Type	Value	Field name
ID primary key	Int	13	ID
Relational data table number	Int	12324	Table ID
Resource number	Int	4324	Resource code
Resource name	Int	131432	Resource name
Resource relation data ID number	Int	54545	Resource ID
Description	Int	85654	Description

resource; user-user means the user is associated with other users who have similar interests; user-resource feature means the user is associated with certain resource hobby features of the user [20]. It is inconvenient for students to learn independently according to their own conditions, which brings a lot of inconvenience to the management of various resources. The reconstruction of various teaching resources results in low utilization of many storage equipment, and subsequent maintenance costs gradually increase. It also brings a certain economic burden. To facilitate management and design, a user's certain hobbies and other users with similar hobbies can also be treated as resource topics, and then users can be associated through resource topics, as shown in Figure 4. According to the above analysis, when an authorized user logs in to the system, the module will first generate resource topic information for the current user from three aspects, the resource itself, the user's hobby, and the resource characteristics, and then it will search for suitable resource information according to each resource topic, and after a series of filtering and ranking, it will generate a recommendation list for the current user. The core task of this module has two steps: one is to generate resource themes, and the other is to search for suitable resources according to the themes.

This design can be more flexible to recommend the required teaching resources according to the user's expectation; by configuring a combination of different recommendation engines, it can produce different information of the recommended list of resources to meet the user's expectation. If we study carefully, we can find that the recommendation engine is a recommendation strategy algorithm. Different users may require different recommended resources due to various reasons, some research users may like novel teaching resources, while other users may only focus on the type of resources they registered when they registered, so to meet the requirements of each type of user to the greatest extent, various recommendation strategies can be combined through the configuration of their behavioral data. The recommendation of teaching resources can be done by combining various recommendation strategies through the configuration, using the behavioral data of the user, and the hobbies registered at registration. After various recommendation strategies, the original list of recommended resources is generated, and then these resource lists are filtered, sorted, and merged to finally generate my recommended resource list, which is presented to the current user's interface in various visualized ways for the user's browsing and downloading.

4. Analysis of Results

4.1. Performance Results of the English Digital Resource Library for Higher Education on the Cloud Platform. The purpose of system testing is to check whether the software

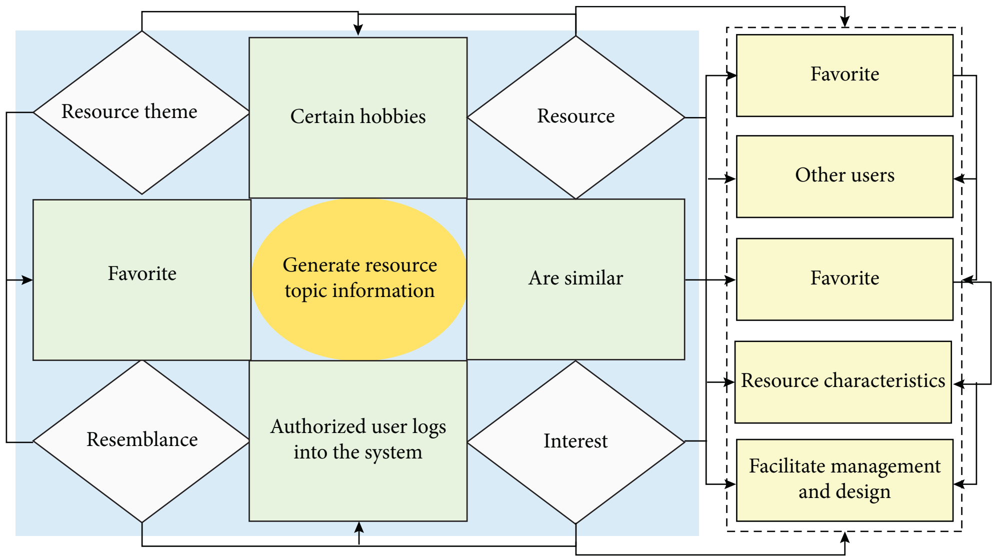

Figure 4: Map of ways to reach out to users and resources.

system meets the requirements; through testing, we can immediately find out the possible logical or physical errors in the software system and then better improve and optimize the system. This repository system is mainly used by many teachers and students, and the testing of this repository system is completed by functional testing and performance testing to ensure the normal operation of the system. To build the test environment, this repository uses the Eucalyptus cloud computing platform to build a private cloud environment and deploys Hadoop cluster, HBase, and MySQL database on it to store and manage various resources. This repository private cloud platform requires 10 physical servers, and the specific configuration and installation components are shown in Table 2.

Functional testing (also known as black-box testing) is a type of testing that only needs to confirm whether the module is functionally complete and correct, without focusing on the specific logic code. Finally, the test cases of the system are written according to the actual situation of the test results, and then the bugs in the system function can be modified immediately to ensure that the system works properly. All the test cases in this use case table cover all the core functional points, and all of them have passed the tests, responsible for the parameter settings of the entire system, including user management, authority management, file storage path management, announcement management, and database management. To ensure that the repository can better serve many students and teachers, it is necessary to test the resource storage performance, system swallowing metrics, IO response speed, and system response time of this repository. To ensure the integrity and correctness of the repository resources, three copies of each resource file are stored on the Hadoop resource cluster. Since the target users of this repository system are teachers and students of the school, although the school users may be over 10,000, the possibility of operating this repository system at the same time is very low, and it is known from experience that the amount of simultaneous online users will not exceed 1000, and the size of relevant resources in the repository is within 100 M. In summary, this test establishes 1000 users, and each user uploads 100 resource files of size 100 M once, the total size of the resource files is 10 TB, and each resource file has 3 copies, so it takes up a total of 30 TB space. To facilitate resource management, a user folder is created for each user in the cluster resource folder. Since a large amount of test data is used for this test, a shell script is executed to simulate the upload of the resource files, as shown in Figure 5.

In today's era, with the increasing amount of information, large data storage has become possible. According to the survey, the size of resource files generally does not exceed 5 G. To test the upload performance of large resource files, we prepare a large file of about 5 G and upload it synchronously through this repository system, which takes a total of 12430.4 seconds, and when downloading the large file, it takes a total of 11895.2 seconds, which meets the user's expectation. To simulate the concurrent load of certain users, monitor the performance of this repository system in real time, conduct a comprehensive test of the architecture of this repository, minimize the test time, and optimize the performance of this system to confirm and find problems early, the following LoadRunner test tool is used to conduct a load test of this repository system. It solves the problem that it is difficult for users to select resources. This function first classifies the uploaded resources according to the content of the resource, obtains the resource theme relationship, and then forms the resource theme model. This time, we recorded a series of operations such as user login, resource browsing, resource uploading, resource downloading, and logging out and then created a script to define load test scenarios, run scenario management, and monitor load tests to understand the performance of this repository and potential bottlenecks in real time.

After functional testing, the integrity of this repository system, the independence of resource data, and the high cohesion and low coupling of system modules are ensured; after performance testing, the high efficiency of system

Table 2: Physical equipment of the infrastructure platform.

Server 1 physical equipment situation		Server 2 physical equipment situation	
Machine name	Cloud platform front-end node	Machine name	Cloud platform back-end node
CPU	Intel E5-2609 V4, 4 cores	CPU	Intel E5-2609 V4, 4 cores
RAM	8 G	RAM	8 G
Disk space	2T SATA hard drive	Disk space	2T SATA hard drive
IP address	192.168.88.100	IP address	192.168.88.101
Installation components	CLC, Walrus, CC, SC	Installation components	NC

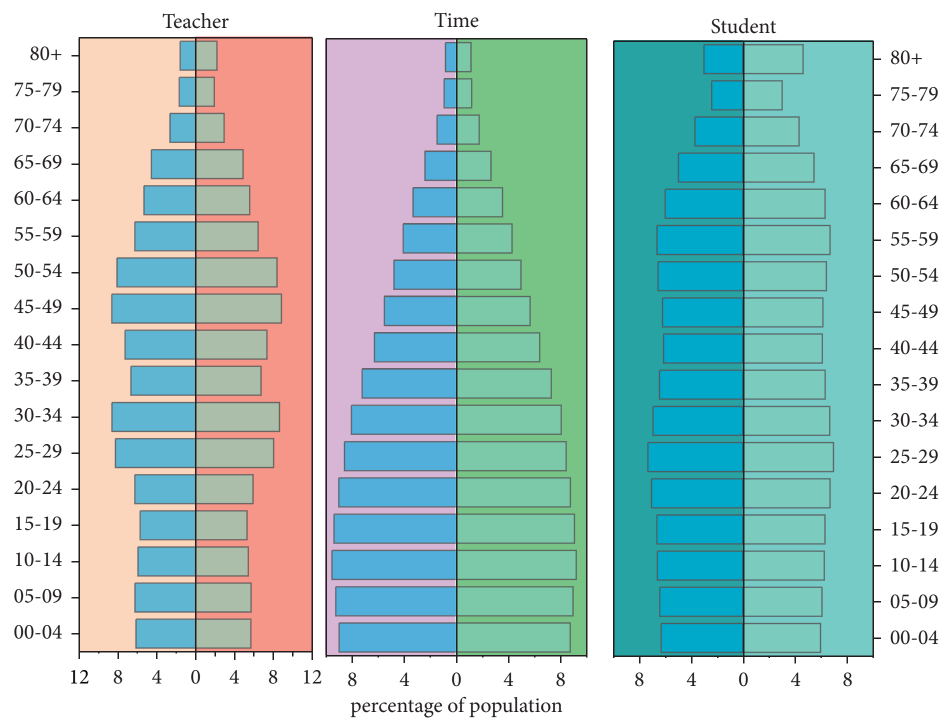

Figure 5: Analysis results.

access, the fault tolerance of resource data, the high scalability of resource servers, and the load balancing of data nodes of the repository are ensured. In summary, the number of interactions per second processed by this repository is relatively smooth, the load balancing capability is qualified, and the system response time is within the acceptable range of users, which is in line with the advantages of cloud computing for large-scale applications. Firstly, the test environment and the steps to build and publish to the private cloud platform are given, then the functional tests of the business functions of this repository are conducted, and some core test cases are given; secondly, the system performance tests of the business functions of this repository are conducted using the LoadRunner software tool, and after analysis and synthesis, the conclusion that this repository meets the initial requirements of users is given.

4.2. Analysis of Experimental Results. After testing, the system was able to accurately verify the normal login of legitimate users, accurately identify different permissions of different users, and smoothly access different management interfaces according to the user's click operation requirements. Logging into the system as different users, they visited the front page of the system and clicked on any resource to test whether they could browse resources, retrieve resources, download resources, collect resources, and evaluate resources; users other than visitors visited the back page of the system to test whether they could upload resources, review resources, modify resources, and delete resources. After the test, the results are as follows: all users can browse resources and retrieve resources; users other than visitors can download resources, collect resources, and evaluate resources; teacher users and resource administrators are allowed to upload resources; load test is a test method to test whether the system can work properly within a certain load level. Generally, you can test by increasing the number of accesses at the same time. For example, the first 50 people access the system at the same time to observe the system condition; if the system is normal, then increase the amount of access until the system cannot afford to crash.

In terms of the pedagogical effectiveness of the resources, teachers generally have a high level of agreement that the EngageNY platform digital education resources provide greater progress for students. Also, from RAND Corporation, a survey of teachers in CSSS-adopting states about the instructional effectiveness of EngageNY and other resources for themselves or their students showed that, across all dimensions, significantly more teachers felt positive about the instructional effectiveness of the EngageNY platform resources than about the instructional effectiveness of other resources. Then, the appropriate resource information will be searched according to each resource topic, and after a series of filtering and ranking, a recommendation list of the current user can be generated. This is because mathematics teachers generally believe that EngageNY is more likely to provide students with opportunities to explain learning and demonstrate teacher work, with more emphasis on conceptual understanding, procedural skills, and practice for the same amount of instructional time and intensity. English teachers who used EngageNY felt that the platform provided students with opportunities to read nonfiction texts of sufficient complexity to greatly enrich their vocabulary and practice skills, as shown in Figure 6.

The planning and construction of the resource bank must be scientific and reasonable to maximize its effectiveness and to make its utilization rate sustainable. At the same time, the content and modules of the resource library should be determined by combining the teaching objectives of higher vocational English and the learning characteristics of higher vocational students. The construction of the resource library should be student-centered, and the resources should be summarized and integrated according to the students' interests and employment-oriented so that students can find the contents they are interested in and can apply them to their studies in the resource library. In addition, all the contents in the resource library must be divided into different categories and clear. First of all, two modules can be set up according to the classification of courses, basic English module and professional English module, among which professional English should be divided into logistics English, mechanical English, automotive English, secretarial English, and other submodules; then, set up subcategories under the major course modules: teaching courseware, microlesson videos, exercises, test questions, skills' training, vocational examinations, and other contents so that teachers and students can quickly find the materials they need.

The construction of the English resource library is not a one-step, ultimate process, but a process that needs to constantly develop and improve with the development of education, so the resource library should make full use of the advantages of the cloud platform to implement dynamic management after the initial completion and adjust at any time according to the needs of teachers and students and development changes. In the process of putting it into use, a person should be assigned to be responsible for the management, timely handling, and repair of problems and regularly collect feedback and suggestions from users to effectively optimize the management and content of the repository. At the same time, the content of the repository should be constantly adjusted and updated according to the changes of relevant professions and social needs after the

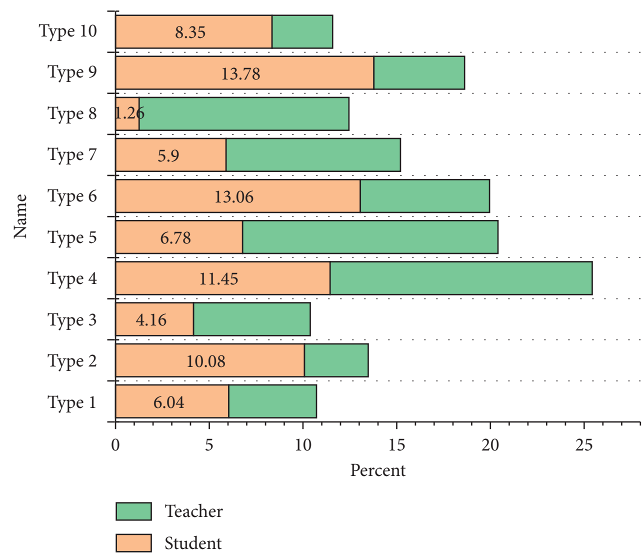

Figure 6: Teaching effectiveness.

repository has been built. Through some incentive mechanisms, users of the repository can be encouraged to upload some useful materials that are not available in the current repository, and then the administrator will include them in the repository after the screening so that the users of the repository can become builders at the same time so that the construction team of the repository can grow and improve the repository, as shown in Figure 7.

Overall, in the second round of teaching practice, there was no significant difference between the scores of the two groups on the accompanying test, which verifies that the application of digital teaching resources from the initial adaptation to the emergence of teaching effectiveness is not achieved in one or two class periods. The existence of significant differences on the topic in the teaching practice is related to the application of digital teaching resources, with the help of which the author carried out rich teaching activities and strengthened the practice of sentence variation in a subtle way, in which the application of digital teaching resources was first seen to be effective.

Overall, as shown in Figure 7 of the ratio of classroom teaching behavior category analysis in group A, the ratios of teacher-student behavior in the experimental class were 53.86% and 46.14%, respectively, and the ratios of teacher-student behavior in the control class were 60.43% and 39.57%, respectively. In the second round of teaching practice, the teacher-student behavior ratios in the experimental class tended to be balanced, and the status of teachers and students in the classroom teaching supported by digital teaching resources tended to be equal, and the problems in the first round of teaching practice were avoided in the second round of teaching practice.

Analyzed from the perspective of the actor, the ratio of teacher's behavior in the control class of group A was higher than the ratio of students' behavior; analyzed from the perspective of behavior type, the teacher's verbal behavior was much higher than the students' verbal behavior, the teacher's speaking component was more, the ratio of

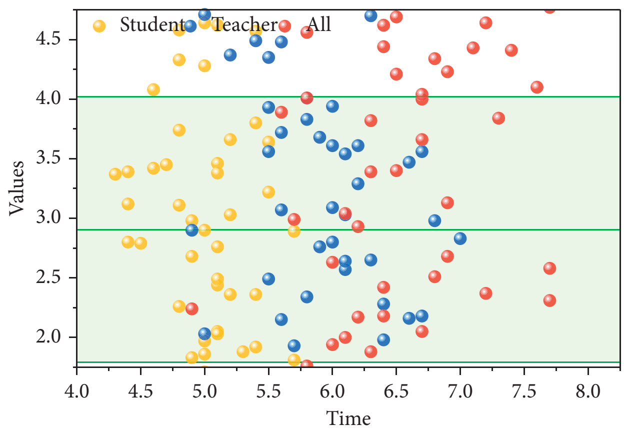

Figure 7: Results of the hands-on follow-on test.

students' activity behavior was higher than the teacher, the ratio of students doing exercises was higher, and the teacher-student interaction was less.

5. Conclusion

The construction of the resource base of any discipline cannot be achieved overnight but requires long-term persistence, constant updating, and dynamic management. This is especially true for the construction of the English resource base in higher education, which should not only be developed and improved with the development of education but also expand the content of the resource base in time with the social trend. Therefore, in the process of construction, the resource library can be dynamically managed by using the dynamic advantages of cloud computing technology in the data processing. Firstly, based on the changing needs of teachers and students, we will adjust, collect feedback from users, and optimize the content of the resource library management. To build a test environment, this resource library uses Eucalyptus cloud computing platform to build a private cloud environment and deploys Hadoop clusters, HBase, and MySQL databases on it. Secondly, according to the relevant professions and social needs, the resource library should be updated with English news, e-commerce information, and international expositions to help students understand the cultural background knowledge of business English, cultivate cross-cultural awareness, and enhance business English application skills. To sum up, the cloud era under scientific development has brought challenges and opportunities for higher vocational English and promoted the process of education informatization reform. To better play the function of cloud platform in the education field, relevant teaching researchers in higher vocational institutions should make full use of cloud computing technology to build the English resource library, combine the advantages of the cloud platform, make the resource library develop in the direction of efficiency, scalability, interactivity, and integration, realize resource sharing, improve resource utilization, provide perfect resource support for teachers' teaching and students' learning, and come out of a suitable path for the creation and application of higher vocational English resources. The aim is to develop a development path that is suitable for the creation and application of English resources in higher education.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

All the authors declare no conflicts of interest.

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Research Article

Application of Deep Learning in Financial Management Evaluation

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The competition among enterprises is becoming increasingly fierce. The research on the financial management evaluation model is helpful for enterprises to find possible risks as soon as possible. This paper constructs the financial management evaluation model based on the deep belief network and applies the analytic hierarchy process to determine the weight of financial management evaluation indicators, which is compared with other classical deep learning evaluation methods, such as KNN, SVM-RBF, and SVM linear. It has achieved an accuracy of more than 81%, showing a satisfactory prediction effect, which is of great significance to formulate corresponding countermeasures, strengthen financial management, improve the capital market system, and promote high-quality economic development. In addition, aiming at the problem of abnormal financial data, this paper uses the new sample dataset obtained by principal component analysis for convolution neural network model learning, which enhances the prediction accuracy of the model and fully shows that deep learning is feasible in the research of financial management prediction, and there is still a lot of space to explore.

1. Introduction

With the development of society, financial intelligence increasingly affects our life and has a great impact on the traditional financial work, which is a topic of concern to enterprises all over the world. By importing data into the database or taking the existing data in the database as the analysis object [1], financial intelligence processes the data according to the financial management model and uses the high-speed and accurate computing power of the computer to quickly obtain the enterprise operation diagnosis report, so as to form a fast and reliable basis for business decision-making [2]. As a popular direction in the computer field, deep learning technology has been closely combined and applied with the financial field. Using reasonable deep learning technology can solve the problem of efficient automatic data analysis in the financial industry, provide valuable prediction information for managers, and provide reliable early warning for healthy institutional operation [3].

Throughout the research trends of financial management evaluation at home and abroad, it mainly focuses on financial evaluation indicators and evaluation models. In the selection of financial management evaluation indicators, existing studies mainly focus on which indicators can accurately predict enterprise crisis [4]. It has experienced the common application stage of multidimensional indicators from single financial ratio indicators and multivariable financial ratio indicators to the combination of financial indicators and nonfinancial indicators [5]. The above studies have achieved certain prediction results, but the selection of multidimensional early warning indicators usually uses statistical methods to test the normality and significance of sample index data and then combined with manual discrimination based on professional ability to select indicators. The selection method is more complex, and there is no unified conclusion on which indicators to select. In the selection of early warning models, early scholars often used univariate model, logistic model, discriminant analysis model, and so on [6]. With the development of information technology, a large number of open real data information can be obtained in the process of enterprise operation. These data can often reflect the past risk status of the enterprise and even some characteristics of the risk of the whole capital market [7]. Therefore, scholars began to apply neural network, support vector machine and other models based on artificial intelligence methods to financial crisis early warning. Generally speaking, the early warning model based on artificial intelligence method has made great progress in the mechanism and systematicness of early warning. It not only overcomes the limitations of the early warning model based on statistical method, such as requiring data to obey normal distribution and complex calculation and analysis, but also has strong fault tolerance and learning ability [8]. At present, artificial neural network has developed to the stage of deep learning network, which is characterized by self-learning and high dynamic adaptability. Therefore, deep learning is also applied to the field of financial management evaluation.

Deep learning can complete a lot of regular, simple, and repetitive work. The application of financial intelligence technology in the financial field has played an important role in improving business efficiency, reducing work errors, and preventing and controlling enterprise risks. This paper studies the financial risk by establishing the financial management evaluation model, which is a quantitative method. It is different from the qualitative analysis. The work is difficult, and the accuracy is low. The model research has higher reliability and uses the analytic hierarchy process to determine the enterprise evaluation index system. This model interprets the historical data, links the characteristics of the data with the financial situation of the enterprise, and then uses the existing data to analyze and predict the future, so as to ensure the accuracy of the prediction.

2. Related Work

Ng et al. proposed a new fuzzy CMAC (cerebellar model articulation controller) model based on reasoning component rules as a new method for bank fault classification and early warning system [9]. Artificial neural network is introduced into financial management evaluation for the first time. Artificial neural networks not only deal with the lack of data errors, but also allow for timely adjustment of internal control parameters. Erhan et al. have proved through practice that the unsupervised training method can better describe the complex functional relationship, which provides a good reference for financial risk early warning. Through the establishment of Yahoo information bulletin board, Jones studied the impact of network information on financial management by using the method of deep learning [10, 11]. Through the establishment of online information bulletin board, Jones reduced the fluctuation of stock price and found that investors' differences of opinion may reduce risk and increase turnover. Through the analysis of stock related blog information in support vector machine, Choudhury found that the fluctuation of stock price will be affected by blog content [12]. Tetlock conducted a 24-year analysis of 500 listed companies [13] and counted the negative words in various reports in this period through the method of deep learning. On the basis of the relationship between corporate income and stock income, this paper points out that the negative words in the news reports of listed companies can predict the decline of listed companies' profits and reevaluate the listed companies. Under the pressure of trading, news content may capture some information that is difficult to quantify, which has a certain early warning function in media reports. Najafabadi et al. abstracted the deep learning algorithm into data representation through the hierarchical learning process [14]. This method has attracted great attention from data science. It is widely used to solve problems, such as network security, medical information, national intelligence, and marketing. Jason Kuen and chin poo Lee applied deep learning to the representation of visual tracking invariance [15] and achieved good results through strong spatiotemporal constraints and stacking slow convolution tracking. Yudistira and Kurita [16] proposed that deep learning processor has become the most potential solution to accelerate deep learning algorithm and pointed out the disadvantage of low efficiency of assembly instructions written by deep learning, which puts forward higher requirements for the research of deep learning.

To sum up, although there are many researches on deep learning at home and abroad, covering a wide range of fields, they mainly focus on theory, speech recognition, and image recognition, which are the feature judgment of known information and lack of relevant empirical research. Many literature studies show that deep learning can well describe complex functions, and financial management evaluation can also be used as a complex function judgment, but so far, deep learning has not been used in the research of financial management evaluation. Based on the previous research, combined with the characteristics of financial management, this paper applies deep learning to the evaluation model of financial management.

3. Evaluation Modelling Based on Deep Belief Network

3.1. Deep Belief Network Model. Deep learning is a category of machine learning that focuses on neural networks. Machine learning can be applied to image, speech, pattern recognition, weather prediction, stock price prediction, gene expression, and content recommendation. This is very similar to the recognition of images by the cerebral cortex. The deep learning model first extracts the low-level features from the original signal, then obtains the higher-level features from the low-level features, and then obtains the higher-level expression. In the face recognition system, the original signal is the pixel, the low-level feature is the edge of the object, the high-level feature is the contour composed of edges, and the high-level expression is the face. Through training with characteristic data, the error is transmitted from top to bottom to fine tune the network. Based on the parameters of each layer obtained in the first step, the parameters of the whole multilayer model are further optimized. Finally, it classifies according to the high-level characteristics and outputs the prediction results of the model. Deep belief network is one of the mainstream deep learning algorithms [17]. According to the Boltzmann machine model of stochastic neural network, the principle architecture of restricted Boltzmann machine [18] is shown in Figure 1.

$a = (a_1, a_2, \ldots, a_{n_v})^T$ represents the offset vector of the visible layer, $b = (b_1, b_2, \ldots, b_{n_h})^T$ represents the offset vector of the hidden layer, and $W = (w_{i,j}) \in R^{n_h * n_v}$ is the weight matrix. The energy function in a deep confidence network generated by multiple constrained Boltzmann machines for any set of neurons with state vector (v, h) is expressed as follows:

$$E(v, h \mid \theta) = -\left[\sum_{i=1}^{n_v} a_i v_i + \sum_{j=1}^{n_h} b_j h_j\right] - \sum_{i=1}^{n_v} \sum_{j=1}^{n_h} a_i b_j h_j v_i, \quad (1)$$

where n_v is the number of all neurons, v is the state vector, h is the state vector in hidden layer, and n_h is the number of all neurons in the hidden layer, and $\theta = \{a_i, b_j, w_{i,j}\}$ denotes the adjustment factors that limit the Boltzmann machine architecture. Through the energy function defined in formula (1), we get the joint probability distribution of state (v, h), as shown in

$$P(v, h \mid \theta) = Z(\theta)^{-1} \exp[-E(v, h|\theta)], \quad (2)$$

where the expression of $Z(\theta)$ is shown in

$$Z(\theta) = \sum \exp[-E(v, h|\theta)], \quad (3)$$

where $Z(\theta)$ is the normalization parameter. It can be seen that in order to obtain $p(v|\theta)$ and $p(h|\theta)$, the key step is to calculate the normalized parameter $Z(\theta)$. The connection of a DBN is guided and determined by generating weights from top to bottom. RBMs is like a building block. Compared with the traditional and deeply layered sigmoid belief network, it can easily learn the connection weights. The probability of activation of a neural unit in the hidden layer can be calculated by the following formula [19]:

$$P\left(h_j = 1|v, \theta\right) = \sigma\left(b_j^2 + \sum_i \sqrt{2}\, v_i w_{i,j}\right), \quad (4)$$

where $\sigma(\bullet)$ indicates sigmoid activation function. The stochastic gradient algorithm is usually used to find the maximum value of $\sum_{i=1}^{t} \log P(v_i|\theta)$. The momentum coefficient is generally taken as (0, 1). Intuitively, it is understood that if the current gradient direction is the same as the gradient direction of the previous step, the weight update of this step will be increased, and if it is different, the update will be reduced. The depth belief network model adopted is shown in Figure 2.

3.2. Determination of Financial Management Evaluation Index by Analytic Hierarchy Process. The evaluation of financial management objectives of logistics enterprises is a complex systematic project, which requires the establishment

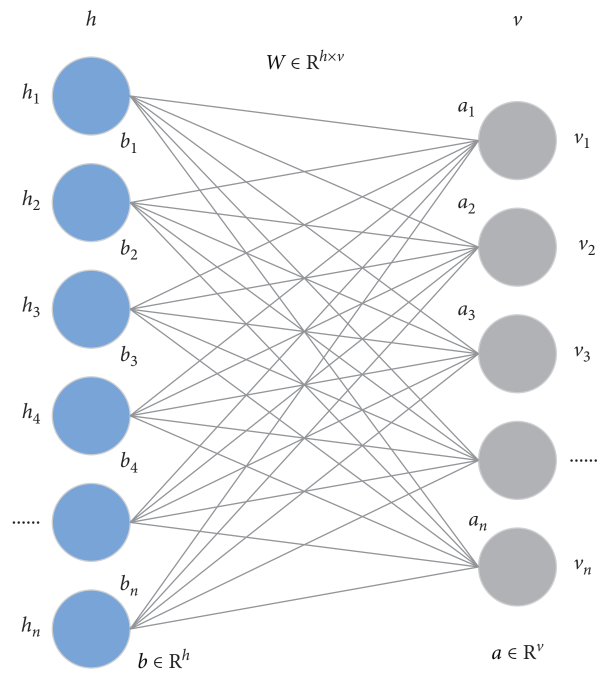

Figure 1: Restricted Boltzmann machine model.

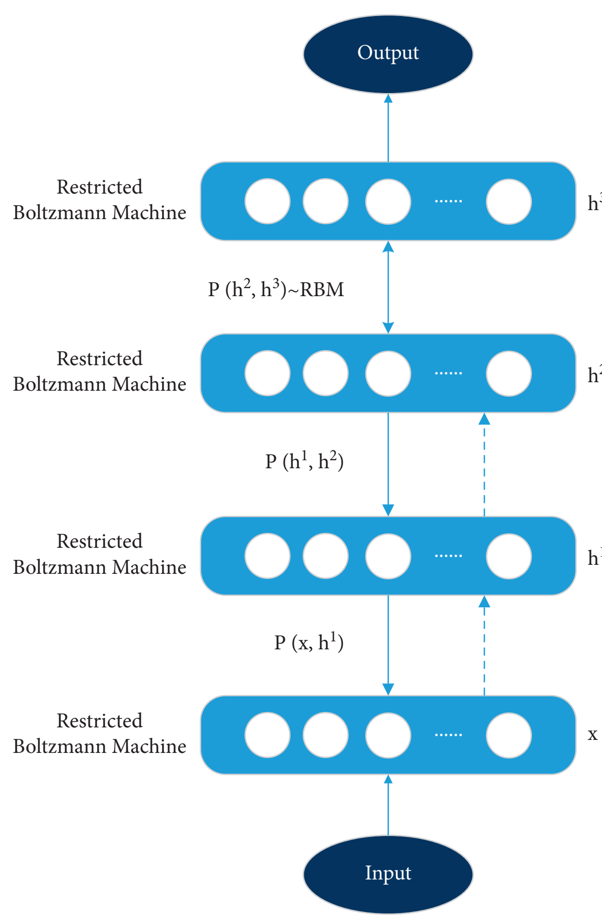

Figure 2: Deep generative model.

of a financial management evaluation system [20]. ST means "special treatment." The policy is aimed at those with abnormal financial or other conditions. The addition of * ST before the stock means that the listed company has suffered losses for three consecutive years, and the exchange makes a delisting warning. The weight of financial management evaluation indicators is determined by analytic hierarchy process. Analytic hierarchy process decomposes the problem into different constituent factors and gathers and combines the factors according to different levels according to the correlation, influence and subordinate relationship between the factors to form a multilevel analysis structure model. It is a model and method for making decisions on complex systems that are difficult to be fully quantitative. The steps are as follows. First, establish a financial management evaluation index system. In order to make a correct evaluation of financial management, we should start from the corporate governance structure; establish the financial management evaluation system from the perspectives of management decision-making and external environment. The corporate governance structure, management decision-making and external environment evaluation are composed of some related elements. See Figure 3 for details.

Then, the judgment matrix A is constructed to obtain the weights of $U1$, $U2$, and $U3$ of the evaluation index system. As an example, the calculation process is illustrated. For the above evaluation index system, the expert group believes that in the evaluation of financial management, corporate governance structure ($U1$) is more important than management decision ($U2$) and external environment ($U3$), and the management decision is more important than the external environment; then $A = \begin{bmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{bmatrix}$.

Calculate the product Mi of each row element of the judgment matrix, and then calculate the nth root of Mi. Finally, normalize the vector $[W_1, W_2, W_3]^T$ and calculate the index weight W_i:

$W_1 = \overline{W}_1 (\sum_{l=1}^{n} \overline{W}_1)^{-1} = 0.540$, $W_2 = \overline{W}_2 \ (\sum_{l=1}^{n} \overline{W}_2)^{-1} = 0.297$, $W_3 = \overline{W}_3 (\sum_{l=1}^{n} \overline{W}_3)^{-1} = 0.163$.

Calculate the maximum eigenvalue of judgment matrix A, $|\lambda_{\max}|$:

$$A \cdot W = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ \cdots \\ W_n \end{bmatrix}. \tag{5}$$

$(A \bullet W)_1 = 1 \times 0.5396 + 2 \times 0.2970 + 3 \times 0.1634 = 1.624$. Similarly, $(A \bullet W)_2 = 0.894$, $(A \bullet W)_3 = 0.4922$. The last step is consistency testing. When $n = 3$, $R_1 = 0.58$, the judgment matrix has satisfactory consistency. Therefore, the weight of $U1$, $U2$, and $U3$ is [0.5396 0.2970 0.1634]. Other index weights can be calculated according to the above method, and the calculation results are shown in Table 1.

When $C_n = 0.0048$, $R_n = 0.90$, and $C_{R1} = 0.0054$, the judgment matrix has satisfactory consistency. When $C_{I2} = 0.0192$, $R_{I2} = 0.58$, and $C_{R2} = 0.0562$, the judgment matrix has satisfactory consistency. When $C_{I3} = 0.0268$, $R_{I3} = 0.58$, and $C_{R3} = 0.0562$, the judgment matrix has satisfactory consistency. The weight distribution data of indicators at each level are summarized in Table 2.

3.3. Intelligent Detection Model of Financial Data. Time series data is a data column recorded by the same unified indicator in chronological order. All data in the same data column must be of the same caliber and must be comparable. As IOT brings a large amount of time series data, we need to time slice the time series data. The traditional time-series data processing methods include median, extreme value, deviation, variance, year-on-year, month-on-month, and periodic methods. These methods can only roughly summarize the data and form a preliminary understanding. The overlapping slicing method of sliding window is used in this paper. This method sorts and counts the target data according to the time sequence, delimits the length and size of each window, summarizes and calculates the characteristics of each time period window, analyses different data with the same dimension in continuous time periods, and obtains the change trend of the target data. In this paper, it will be solved by convolution neural network, as shown in Figure 4.

Firstly, after the training data is processed by zero mean, principal component analysis is carried out to reduce the input parameters of convolutional neural network model and reduce the correlation between input factors. Then, the new sample dataset obtained by principal component analysis is used for convolutional neural network model learning, and the parameters in convolutional neural network are continuously adjusted by gradient descent. Finally, the test sample data are applied to the model to verify the prediction accuracy of the model.

Since this study only considers the impact of historical data on future enterprise finance, a one-dimensional convolutional neural network is adopted. The model includes two convolutional subnet works, as shown in Figure 5. The input layer is m k-dimensional index data output from formula (4), and the output layer is two classifiers. The convolution layer is used to extract different features of the input layer, the linear rectification layer is used to activate neurons in the network according to the linear function, the pooling layer is used to reduce the data dimension, and the full connection layer is used to combine all local features and calculate the final classification result.

In this study, the input data for one-dimensional convolutional neural network is the k-dimensional orthogonal feature Y'_{ij} of M companies. Then, three convolutional subnetworks are used to deeply learn the orthogonal feature data of enterprises. The first convolutional network selects 128 convolutional cores with the size of $1 * 3$, and the second convolutional network selects 128 convolutional cores with the size of $1 * 4$. The third subconvolution network selects 128 convolution cores with size of $1 * 5$. The calculation formula is as follows:

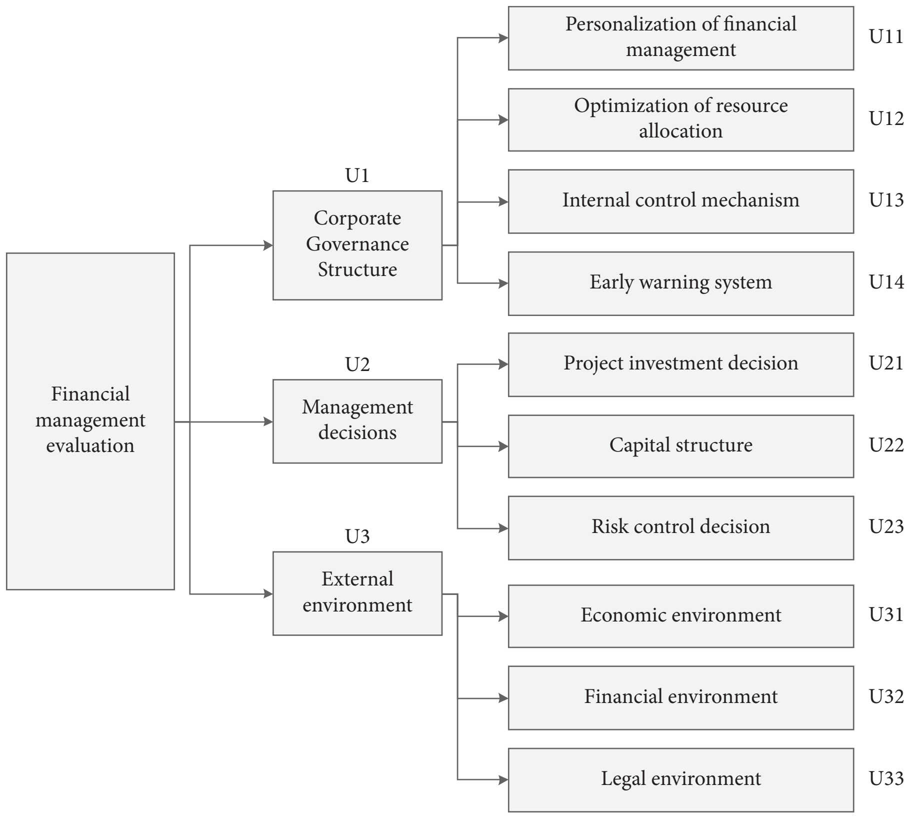

Figure 3: Comprehensive financial management evaluation system.

Table 1: Index weight.

	$U11$	$U12$	$U13$	$U14$	Weight
$U11$	1	2	3	4	0.6532
$U12$	1/2	1	2	3	0.3841
$U13$	1/3	1/2	1	3	0.2890
$U14$	1/4	1/3	1/2	1	0.1206

Table 2: Weight distribution data.

Index	$U1$	$U2$	$U3$	$U11$	$U12$	$U13$	$U14$
Weight	0.5396	0.2970	0.1634	0.4832	0.2717	0.1569	0.0882
Index	$U21$	$U22$	$U23$	$U31$	$U32$	$U33$	
Weight	0.6369	0.2583	0.1048	0.5278	0.3325	0.1397	

$$X^{(l)} = f\left(W^{(l)} \cdot X^{(l-1)} + b^{(l)}\right), \quad (6)$$

where $X^{(l)}$ and $X^{(l-1)}$ are the neuron output values of layer l and layer $l-1$, W^{l} is convolution kernel, and b is offset. The activation function adopts a modified linear unit. For the input x, the weight vector is ω, and the output with offset b is max $(0, \omega x + b)$. The linear activation function simply sets the threshold to zero, which greatly reduces the computational overhead. Moreover, compared with the expensive operations (exponents, etc.) of sigmoid and tanh neurons, relu can be activated through a simple zero threshold matrix and is not affected by saturation. Meanwhile, $L2$ norm is used to normalize the fitting cost, as shown in

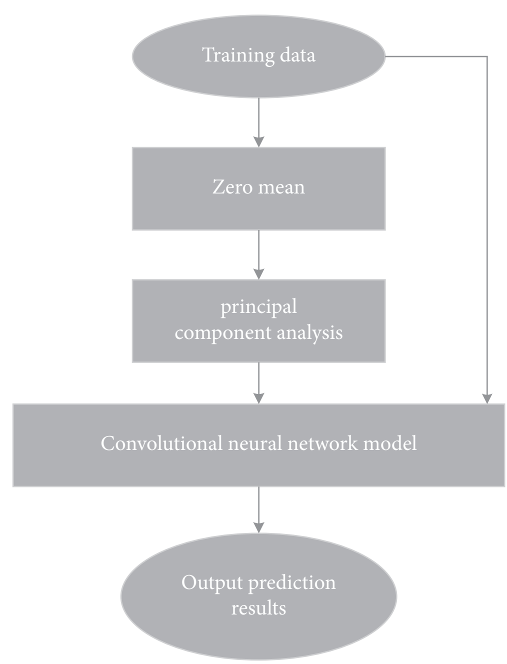

Figure 4: Financial management model framework based on convolutional neural network.

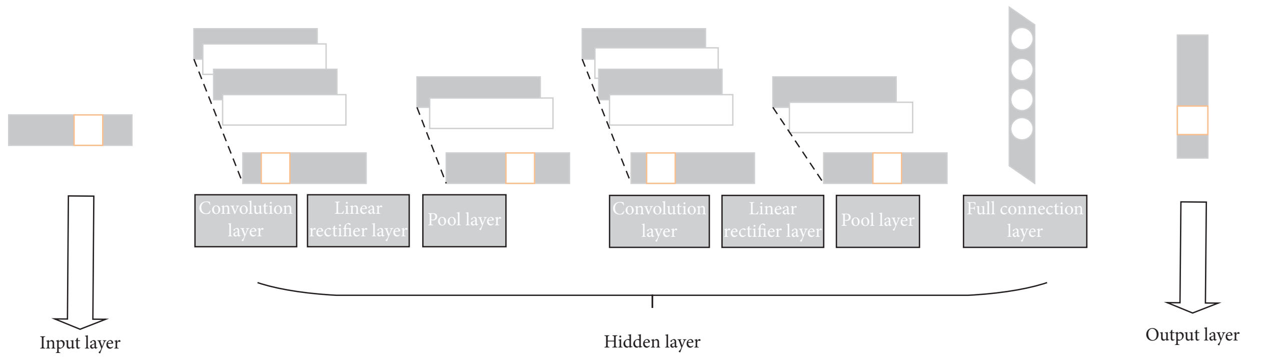

Figure 5: Framework of one-dimensional convolutional neural network model.

$$C = -n\sum_{1}^{x_j}\left[y_i \ln a_j^l + (1-y_i)\ln(1-y_i)\right] + n\sum \lambda\omega^2, \quad (7)$$

where the first term represents the cross entropy cost, the second term is the sum of squares of all weights added, and then the factor used $\lambda/2n$ to make quantitative adjustment, and $\lambda > 0$ is called the normalization parameter. The third convolution subnetwork outputs to the full connection layer and then outputs the final binary result; that is, whether the enterprise is ST in this study, the output result of ST enterprise is 0 and that of non-ST enterprise is 1 [21]. At the same time, this study uses the maximum pooling method to pool local feelings and selects the flexible maximum method to solve the problem of slow learning.

4. Results and Safety Analysis

4.1. Data and Empirical Design. In the future, A-share may form a two-way benign expansion of supply and demand, and the regulatory authorities' policies on its stock market are also more effective and in place, which is conducive to the dynamic balance of supply and demand. There are ST system and * ST system in stock market. From the perspective of data availability and effectiveness, it is a reasonable method to use enterprise stock ST or * ST as the symbol of enterprise financial crisis.

This paper first selects the companies that are ST and * ST (hereinafter referred to as ST companies) and then finds out the corresponding companies of each ST or * ST company (hereinafter referred to as non-ST companies) in the companies with normal financial conditions according to the industry and average total assets. Use the financial index data of ST companies and non-ST companies in the previous years of 2016 to predict whether there will be a financial crisis in 2016 (by ST or * ST), compare with the actual situation, count the accuracy of the prediction, and conduct empirical analysis. This paper selects a total of 3513 companies. The reason for data normalization is that the measurement units of each data are different, and the processed data will be between 0 and 1. If the data is not normalized, the gradient descent is carried out in one unit, so its descent step in each direction is the same. Non-standardized data will cause the gradient to follow a zigzag route in the direction perpendicular to the contour line when the gradient decreases, which will make the iteration very slow. In general, normalization can make the order of magnitude of each stock index correspond to the length of gradient decline [21].

This paper has conducted four empirical analyses, and the selection of data quantity is shown in Table 3. This paper has conducted four empirical analyses, and the selection of data volume is shown in Table 3. Taking the data of the first few years of 2016 as the training set and the data of the next few years of 2016 as the prediction set, the output result of no financial crisis is 0 and the output result of financial crisis is 1. The judgment result is recorded as x, the actual situation of the company is recorded as y, x and y are 0 or 1, the number of companies in the prediction set is n, and the calculation formula of accuracy P_a is

$$P_a = \left(1 - N^{-1}|X - Y|\right) \times 100\%. \quad (8)$$

4.2. Outcome Evaluation Criteria. Because each simulation will randomly take an initial value, the results of each simulation may be different. The experiments were conducted in four groups based on the size of the years of data selected. In general, the nodes in the hidden layers have an impact on the prediction results. If the number of hidden layer nodes is too small, the network cannot have the necessary learning ability and information processing ability. If too much, it will not only increase the complexity of the network structure and make the network more likely to fall into local minima in the learning process but also make the learning speed of the network very slow. The neural network structure has two hidden layers, and the number of them can be determined by the following formula:

$$\begin{aligned} L &= \alpha^2 + (m+n)^{1/2} \\ &= \log_2 m, \end{aligned} \quad (9)$$

where m and n represent the nodes of the output layer and the input layer, respectively, α can be any value between 1 and 10. These methods can only obtain feasible initial values for the nodes of the hidden layer, and this number usually needs to be corrected during training and learning. Generally, two methods of gradually increasing and gradually decreasing are used to correct the number of nodes in the

Table 3: Empirical quantity statistics.

		ST		Non-ST		Total	
		Number of companies	Amount of data	Number of companies	Amount of data	Number of companies	Amount of data
2 years	Total of training set and test set	55	2805	55	2805	110	5610
		55	2805	55	2805	110	5610
		110	5610	110	5610	220	11220
4 years	Total of training set and test set	51	5151	51	5151	102	10302
		51	5151	51	5151	102	10302
		102	10302	102	10302	10506	20604
8 years	Total of training set and test set	26	4576	26	4576	52	9152
		26	4576	26	4576	52	9152
		52	9152	52	9152	104	18304
12 years	Total of training set and test set	17	3842	17	3842	34	7684
		17	3842	17	3842	34	7684
		34	7684	34	7684	68	15368

hidden layer to achieve the expected value and reduce the error to a reasonable range. This study uses formula (9) to calculate the hidden layer nodes and finally obtains the nodes of each network, as shown in Table 4.

From the results shown in Figure 6, the accuracy of the model in predicting whether an enterprise will have crisis can be maintained at more than 81%, which shows that the model based on deep learning has a general prediction effect for A-share listed companies, the more the years of data used for prediction, the higher the accuracy of prediction.

In order to test the effect of model training, this study inputs the test data into the model after the above training and observes the accuracy of the test data. From Figure 7, it can be seen that after training, the accuracy of the model on the training set is 79.1%, and the accuracy on the test set is 91.34%. The results show that the accuracy of the test set is slightly higher than that of the training set, which proves that the model has better generalization ability.

4.3. Intelligent Analysis of Financial Data Based on Deep Learning. In the pretraining stage, each layer of RBM network is trained separately and unsupervised to ensure that the feature vectors are mapped to different feature spaces and retain the feature information as much as possible. It is pretrained by an unsupervised greedy layer-by-layer method to obtain the weight. In this process, the data is input to the visible layer to generate a vector V, which is transmitted to the hidden layer through the weight W to obtain H. In the last layer of DBN, a BP network is set up to receive the output eigenvector of RBM as its input eigenvector and train the entity relationship classifier supervised. Moreover, each layer of RBM network can only ensure that the weight in its own layer is optimal for the eigenvector mapping of that layer, not for the eigenvector mapping of the whole DBN. Therefore, the backpropagation network also propagates the error information from top to bottom to each RBM layer and fine-tune the whole DBN network. The process of RBM network training model can be regarded as the initialization of the weight parameters of a deep BP network. The naive Bayesian classifier in this paper is realized by MATLAB programming. In this section, the financial data of traditional indicators are

Table 4: Network node setup.

	2 years	4 years	8 years	12 years
First hidden layer	8	14	29	32
Second hidden layer	4	9	10	10

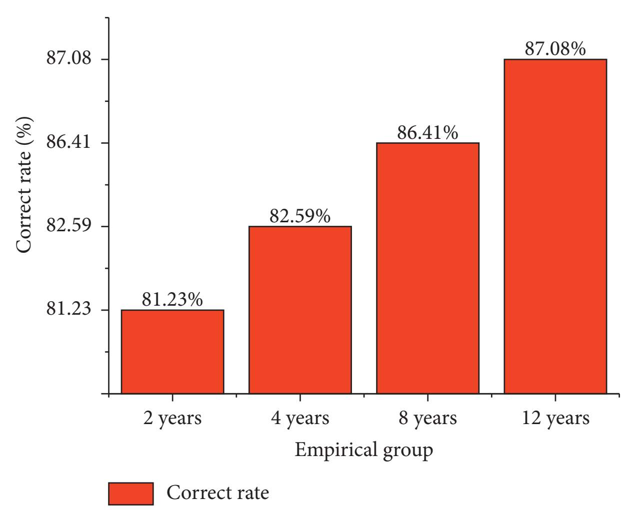

Figure 6: Empirical results.

Figure 7: The accuracy of training and testing datasets changes with the learning cycle.

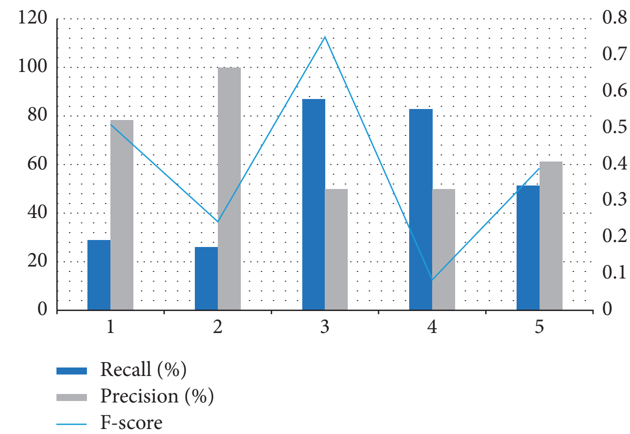

Figure 8: Comparison diagram of various forms of model identification. (1) Traditional model. (2) Timing standard in the form of difference. (3) Time series standards in ratio form. (4) The first relative value form of the timing standard. (5) The second relative value form of the timing standard.

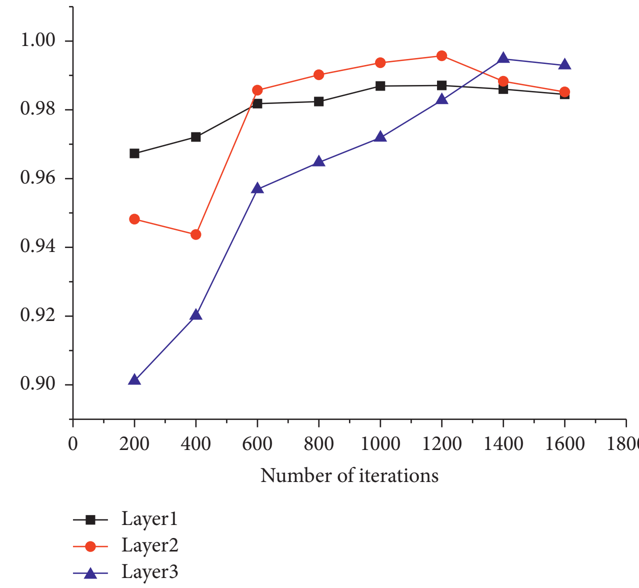

Figure 9: DCNN classification accuracy of different hidden layers.

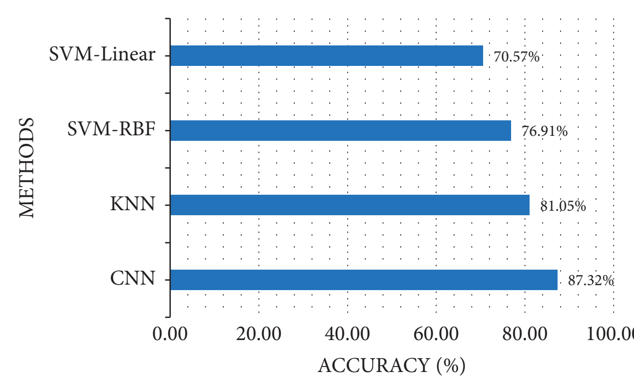

Figure 10: Comparison of prediction accuracy of different methods.

processed by the time-series construction method proposed above and then input into the classifier. After running, the classification effects of traditional models and various forms of models can be obtained. The operation results of each model are shown in Figure 8.

In Figure 8, the recall rate of the time series index model in the ratio form and the first relative value form is the highest. In terms of precision, the time series index model in the form of difference is the best. It can also be seen that the recall rate and precision rate show the law of one change and the other. The comparison of classification accuracy of DCNN under different hidden layer structures is shown in Figure 9.

According to Figure 10, hidden levels 1, 2, and 3 show good classification accuracy, all reaching more than 91%. After 600 iterations, the classification accuracy of the second level reaches 98.57%, which is the maximum of the classification accuracy. Therefore, the convolutional neural network model with 3-layer hidden layer structure has good classification accuracy.

In order to further prove the effectiveness and superiority of convolutional neural network model, this work compares it with traditional classical machine learning early warning methods. The methods used for comparison include *k*-nearest neighbor (KNN), support vector machine Gaussian kernel (SVM-RBF), support vector machine linear kernel (SVM linear). The basic parameter setting of the test is the same as the above. The number of neighbors in KNN is set to 6 and the kernel function parameter of support vector machine is set to 10. Making the weight smaller and smaller, then its corresponding loss function will be smaller and smaller, finally achieving our goal. The smaller the value of the loss function, the more accurate the prediction is. The prediction accuracy of the model established in this study can reach 81.65% showing a good financial prediction effect. This is because convolutional neural network can better learn the correlation between various indexes and extract the most effective abstract features, so as to ensure the accuracy of prediction results.

5. Conclusion

In order to improve the accuracy of corporate financial management evaluation, this paper constructs a financial management evaluation model based on deep learning and uses the data of A-share listed companies from 2007 to 2020 to explore whether deep learning can build a generally applicable financial management model for listed companies. By using the data of different years, it is also concluded that the more the data years the model constructed in this paper uses, the higher the prediction accuracy. The test results show that the intelligent analysis of financial abnormal data based on deep learning is also effective and accurate. Finally, the effectiveness and practicability of the intelligent analysis method are proved by an example.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

Acknowledgments

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Research Article

Design of the Museum Interactive Lighting System Based on the Digital Twin Technology

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With the improvement of people's cultural level, more and more museums are being built or renovated. The design of lighting products for museums is a specialized field that requires designers to take into account a variety of factors, such as safety, presentation, and maintainability. As museum lighting systems meet the needs of conservation, visitor experience, and maintenance, the traditional design process is limited by the experience of the designer and the actual situation of the museum, and the actual light conservation effect of the exhibits is difficult to quantify. We have designed a digital-twin-based intelligent lighting system for museums, which can facilitate museum managers to quantify and manage the light life of exhibits while providing a more immersive viewing experience and recognition effect for visitors.

1. Introduction

Lighting design is an important part of museum exhibition design [1–3]. Without the existence of light, the audience will not be able to appreciate the form, material, and color of the exhibits [4, 5]. Without the change of light, the exhibition space will lose its vitality and artistic conception [6]. Because the light is directly related to vision, the construction of light environment is also what designers need to pay attention to when planning the exhibition space and the modeling performance of exhibits. Excellent museum lighting should first have the function of cultural relics' protection [7, 8], and the lighting should filter out harmful infrared and ultraviolet rays. At the same time, due to the damage of visible light to some exhibits, it is necessary to consider the quantity of the exhibits. In addition, the design also needs to choose the light source with appropriate color temperature and color rendering so that the exhibits can be clearly viewed by the audience, and the colors of the exhibits can be restored to the maximum. For the lighting of the whole exhibition area, we should control the glare, contrast, uniformity, and other parameters to create a soft and comfortable light environment so that the audience can immerse themselves in it and enjoy it.

Lighting serves the function of museums [9–11]. Museums [12] have three basic functions: "collection and preservation of cultural relics," "protection and research of exhibits," and "education and appreciation." In order to reduce the damage of optical radiation to exhibits, most countries have formulated standards to provide reference values of illumination and limit annual exposure of different exhibits. However, in order to create a good visual environment for the audience, we need to improve the illumination of the exhibits. Due to the reduction of environmental light [13], the ability of recognition will decline, so will the human visual ability, people will not be able to identify the information that the exhibits need to transmit [13]. To solve this contradiction and realize the balance between exhibits' protection and viewing experience are the key points of museum lighting design. In order to make the museum, lighting environment not only provides a good visual experience for the audience but also minimizes the exposure of exhibits in the exhibition cycle; the lighting design must comply with the principles of safety, reliability, economy, advanced technology, energy saving, and convenient maintenance. In addition, many artificial intelligent technologies [14–17] have been used in some display applications [18–20] and also used in the smart city's applications [21–24].

2. Lighting Design of the Museum

2.1. Museum Lighting Design Requirements. In order to solve the contradiction between the aforementioned viewing experience and the protection of exhibits, some museums use infrared induction technology; the lights are on when people come, and the lights are off when people go. In this way, the exposure time is reduced, and the illumination of exhibits can be appropriately improved. Some studies have shown that the exposure time can be controlled when the illumination is properly increased, and no additional damage will be caused to the exhibits. At the same time, lighting design not only pays attention to the experience of the audience but also needs to consider the experience of managers. With the development of Internet of Things technology and mobile devices, some designers provide mobile terminal management software of lighting equipment for museum managers, realizing intelligent management. Traditionally, owners need to operate lighting equipment switch and maintenance on-site. Now, it can be processed through the mobile terminal.

However, the single induction control, fixed illumination adjustment logic, and simple management software cannot meet the growing needs of museum lighting design. Therefore, it is of great practical significance to design multisensor integrated interactive control lighting products and intelligent management software. We designed a museum intelligent lighting system based on digital twin, which realized the interaction between the audience and the museum lighting equipment through a variety of sensor devices and procedures such as target detection, position detection, and illumination detection, dynamically adjusted the best lighting brightness for the audience, exhibition area, and exhibits, and provided quantitative management of exhibits' health for museum managers.

2.2. Problems in the Lighting Design of Existing Museums. At the beginning of the design, we chose a large comprehensive museum for field investigation, evaluated the existing display design of two exhibition halls, and summarized the existing problems in lighting in order to design a lighting system that can take into account the exposure and display effect of the exhibits; see Figure 1.

We sum up the following four problems:

① The glare of the basic lighting is serious, and the point light source used for the basic lighting in the exhibition hall produces a lot of light spots and glare on the glass cover of the exhibits.

When analyzing this aspect, the first thing is to interpret the angle of natural light. When the light is sufficient, the exhibits will have the optimal visual effects.

② The guiding effect of key lighting is insufficient (see Figure 2), and the brightness of some wall washing lighting is too high, and the range is too large, which affects the local lighting (see Figure 3).

For artificial lighting, we can use the halogen lamps at 45° angle, and the exhibits can meet the general viewing requirements of the audience.

③ The local illumination brightness is insufficient, and the focus range is uneven, which leads to poor display effect and unreal appearance.

In addition, the smallpox part of the display space and the light irradiation of the wall facade are coordinated, and the design of the color sense of the ground is more dark. For the precious exhibits displayed in textiles, clothing, paper painting and calligraphy, and other vertical forms, the angle of light must be more rigorous.

④ During the opening period of the exhibition, all the lighting brightness is constant, and there is still a certain amount of exposure when there is no audience to watch the exhibits in part of the time.

When light angles vertically to 30° of the exhibit, viewing the surface of the vertical artifacts does not produce any glare for the best viewing experience, but the light source is best extended to make the edge of the shade softer (see Figure 4).

In view of the above problems, our research objectives include the following: the lighting design system can adjust the exposure level of exhibits according to whether the exhibits are being watched; that is, when the exhibits are being watched, it can provide the best illumination for the exhibits; when there is no audience around the exhibits, it can enhance the guiding effect of key lighting and, at the same time, reduce the basic lighting and local lighting to the minimum safety limit.

2.3. Related Work at Home and Abroad. The balance between exhibits' protection and viewing experience is the core of museum lighting design. The problem of light damage in museum lighting is not a new topic in the field of museum lighting at home and abroad, but the research on museum lighting design is still in the exploratory stage. At present, there are still many problems and deficiencies in this field. The theoretical research and practice of museum lighting without light damage are still at a low level, and a complete design system has not yet been formed. Although some museums began to use infrared induction control lighting and mobile terminal software control lighting schemes, these schemes are still too simple. With the development and improvement of light source equipment, interactive control mode, and digital twin theory in recent years, some new technologies worthy of designers' adoption have emerged. Through theoretical exploration and practical verification, we have applied some research results to our design scheme, mainly involving the following three aspects.

The space light environment of the museum can be divided into basic lighting, key lighting, local lighting, and atmosphere lighting. This paper summarizes the following common space elements and lighting methods: display cabinet space is used to display small precious cultural relics, suitable for local lighting; large-scale cultural relics and art exhibition space, suitable for the key lighting mode; wall

Figure 1: Spot and glare.

Figure 2: Improper setting of key lighting.

Figure 3: Improper setting of local lighting.

washing space is used for paintings, murals, thangka, and other exhibitions, suitable for key lighting methods.

According to the research results of many museums at home and abroad, all sensitive exhibits adopt artificial lighting, which combines general lighting with key lighting, rather than uncontrollable natural lighting. Traditional light sources mainly include halogen lamp, fluorescent lamp, and metal halide lamp, which have their own advantages and disadvantages. However, the survey also found that the LED light source, as a rising star, has the

Figure 4: Continuous exposure of exhibits when no one is watching.

characteristics of energy saving and environmental protection, long service life, adjustable, convenient maintenance, and so on, which make it widely used in the lighting market. In recent years, after the white LED light source came out, it developed rapidly, which provides conditions for the LED light source to be used in indoor lighting. And the relevant research data show that a large number of museums represented by the Palace Museum have generally realized the application of the LED light source in lighting design, and the proportion of museums and art museums considering using the LED light source instead of the traditional light source is as high as 75%.

We finally decided to use the LED light source in this design for the following reasons: small size of LED lamps, easy installation, and debugging; no thermal and chemical damage to the exhibits; the color temperature and brightness of the LED can be easily controlled; high reliability and low maintenance cost. Because the LED basically does not contain infrared light and ultraviolet light, this design selects the LED light source with high color rendering index and only considers the illumination and exposure time to control the exposure of the exhibits in the low color temperature lighting mode.

2.4. Multisensor Fusion and Interactive Control. The intelligent Internet of Things control system connects all kinds of household appliances through the network to realize the functions of data collection, centralized monitoring, and management. The powerful network communication function is an indispensable part of the intelligent Internet of Things system. At present, the mainstream communication technologies used in the control system of intelligent Internet of Things are as follows: fieldbus technology, whose wiring adopts the bus structure, which is mainly composed of three basic parts: power supply, twisted pair, and function module; the power line carrier technology is to transmit analog or digital signals at high speed using carrier mode; wireless technology is a networking mode with WLAN technology as the main connection mode. Wireless technology is usually classified according to the wireless communication protocol, such as wireless Ethernet, Bluetooth, ZigBee, and LoRa. At the same time, the wireless Internet of Things control system also needs to meet the requirements of low power consumption, stability, easy expansion, and grid connection.

In this design, the main hardware devices are LED light source, temperature sensor, humidity sensor, PM fine particle sensor, camera, gateway, and industrial computer. Due to the scene limitation of museum exhibition area, in this design, LED light source, temperature sensor, humidity sensor, PM fine particle sensor, and camera of each exhibition area are connected to the gateway equipment of each exhibition area through the WiFi communication protocol, and the gateway equipment of each exhibition area is summarized to the local area network of the industrial control computer through wired Ethernet.

In order to reduce the exposure of exhibits (see Figure 4), some museums use the infrared sensor to control the light source switch. However, the sensing range of the infrared sensor is limited, and it cannot accurately perceive the real-time position and moving track of the audience in the exhibition area, so its control logic is too simple. Therefore, in this design, the camera is used to capture the overall picture of the exhibition area, and the target detection algorithm is used to detect the audience position algorithm and predict its viewing path, so as to achieve the effective control of lighting and smooth transition. Target detection is one of the key technologies of intelligent video image recognition and individual target behavior recognition. At present, with the development of deep learning technology, target detection algorithm has entered the research track of rapid development. In recent years, a number of excellent deep learning target detection algorithms such as R-CNN, Fast R-CNN, SSD, and YOLO have emerged. These algorithms have excellent detection effect and performance in some open-source target detection video image datasets. Among these algorithms, YOLO algorithm is a rising star. It is a target detection algorithm based on deep learning, which was published by Joseph et al. in a paper published in 2016. Compared with other algorithms, the biggest advantage of YOLO algorithm is its fast detection speed, which is a necessary condition for target detection engineering. Since 2016, the latest version of YOLO algorithm is YOLOv4 algorithm released in 2020. For the original YOLOv1 algorithm, in addition to maintaining the advantages of fast detection speed, great progress has been made in accuracy. Because of the excellent accuracy and speed of YOLO algorithm, it is very suitable for this system to detect the position and trajectory of the museum audience, so we use the most widely used YOLOv3 algorithm to develop the light source interactive control program of this system.

2.5. Twin Digital Platform. The concept of the digital twin platform has been born for decades. When it first appeared, it was defined as product production and real-time virtual presentation. However, due to the shackles of the technical level at that time, this new concept did not get enough attention. With the development of intelligent devices in recent years, sensor technology, hardware and software technology, and computer computing performance have been greatly improved. The concept of the digital twin platform has also been further developed, especially in the real-time monitoring of products and devices in industrial scenes. In 2019, by building the digital twin platform of the exhibition hall and cooperating with the UWB sensor to obtain the real-world indoor positioning data of the audience, some researchers have realized the functions of real-time positioning, hot spot analysis, and pedestrian trajectory tracking in the exhibition hall scene (ref. [5]). In our system, we use the computer vision scheme to get the audience's position in the exhibition hall through the target detection algorithm, which saves the cost of preparing a large number of positioning tags for the audience.

3. Design Details of the Museum Interactive Lighting System Based on the Twin Digital Platform

3.1. Lighting Control and Illumination Detection Hardware. Our design is suitable for a variety of museum exhibition space. In order to better reflect the application effect of this design, we decided to find a real exhibition area of a museum, design the lighting scheme after remodeling, and apply our intelligent lighting system to explore the improvement effect of the existing museum after reconstruction.

The lighting control equipment is mainly composed of the controller, communication module, and LED drive circuit. The controller is STM32F103C8T6 MCU, and the communication module is an ESP8266 wireless network chip. After the equipment is connected to the power supply circuit of LED lamps in the exhibition hall, it can realize the switch and brightness adjustment and receive the light adjustment instructions from the server through the wireless local area network.

The hardware part of illumination detection equipment is mainly divided into the controller, communication module, sensor module, and power supply module. The controller is STM32F103C8T6, the communication module is an ESP8266 wireless network chip, the illumination detection sensor is MAX44009 light intensity sensor, and the power supply module is low-voltage DC power supply. All the environmental data detection devices are sent to the server through the wireless LAN network and stored in the digital twin platform database (see Figure 5).

3.2. Pedestrian Detection and Twin Digital Platform. In this design, we need to install a webcam at the top of the exhibition area which can capture the largest panoramic image and transmit the video stream to the server through Ethernet. The main configuration of the server used in this system is 8-core 16-thread CPU, RTX2080Ti GPU, and 32 GB memory, Gigabit Ethernet card.

The system in this paper uses the method based on deep learning to detect pedestrian targets. In the field of pedestrian target detection, YOLOv3 is widely praised as a good choice. With its excellent characteristics, YOLOv3 can

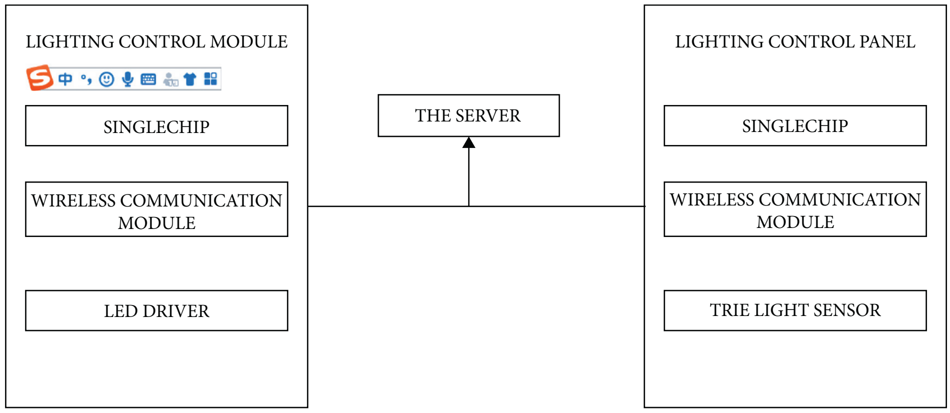

Figure 5: Hardware architecture.

effectively solve the scaling, background clutter, and morphological diversity of pedestrian targets (see Figure 6).

The pedestrian target detection dataset used in this system is divided into two parts, one is the open-source data pedestrian dataset, and the other is the video segmentation dataset, including pedestrian targets captured in the exhibition area of Nanjing Museum and nearby roads. After finishing the dataset, we get 902 images containing pedestrian targets and their corresponding XML annotation files. Another dataset is the video taken by ourselves in the exhibition area of Nanjing Museum and nearby roads. We use labelling annotation software to annotate the captured images and finally sort out 1000 images containing pedestrian targets and their corresponding XML annotation files. Through the synthesis of the above two datasets, a dataset containing more than 2000 pedestrian images is obtained. Following the basic principles of deep learning training and testing, the dataset needs to be divided into two parts: training set and test set. The pictures of the training set and test set cannot be repeated. In the experiment designed in this paper, the author randomly divided the comprehensive pedestrian dataset into the training set and test set according to the ratio of 8 : 2 and then trained and tested the neural network. Finally, the weight obtained from the training can be used to collect the video in the exhibition area to detect the audience.

After detecting the audience in each frame of the video stream (see Figure 7), the program developed by the open computer vision library can calculate the geometric center point of the audience in the picture. Through the conversion between the camera shooting angle and the plane coordinates of the exhibition area, the position of the audience in the exhibition area can be calculated, and the nearest light source can be adjusted to the preset optimal viewing illumination. The illuminance of the distant light source decreases according to the preset value, and only the minimum safe illuminance of the distant exhibition area is maintained.

The above programs are written by using Python programming language, and the audience position information and light source illumination control information are stored in the database for the digital twin platform to read.

3.3. Exhibition Health Twin Digital Platform. The digital twin platform of this system uses Blender software to model the scene and exhibits, and the model is imported into Unity 3D software to develop the whole system (see Figure 8). The digital twin platform is developed with C# programming language, and the client can develop the web version/PC version/APP version according to the requirements. The illumination data can be saved locally or hosted in the cloud, such as Baidu's time series database, which is determined according to the needs of remote management and the networking environment of the site.

For the users of this system, that is, the owner of the museum, we can use this platform to intuitively monitor the exposure of each exhibit in the exhibition cycle, which can not only grasp the health status of the exhibits but also flexibly adjust the exhibition time accordingly. Compared with the traditional fixed exhibition period in which the manager has no knowledge of the exposure of the exhibits, after the introduction of this system, the manager can quantitatively analyze the exposure of the exhibits and then make a more reasonable decision on the exhibition period.

4. Human-Computer Interaction Design Based on Motion Capture Technology

The previous pedestrian detection algorithm focuses on the detection of pedestrian distribution in a large area and then adjusts the illumination of basic lighting and key lighting. For the local lighting near the exhibits, it needs to identify and adjust the viewing state of the audience near the exhibits.

The recognition of the audience's viewing state can be summarized into the category of action interaction in human-computer interaction. In this paper, the most typical action of "leaning to watch" is selected as an example to study, and a set of human-computer interaction schemes based on motion capture technology is designed.

Because this research is in the stage of conceptual design, Kinect DK hardware of Microsoft company and its supporting body tracking SDK are used in the technical prototype. Several Kinect DKs need to be installed near the exhibition stand to ensure that the pedestrians around the exhibits are within the camera's field of vision. Kinect DK

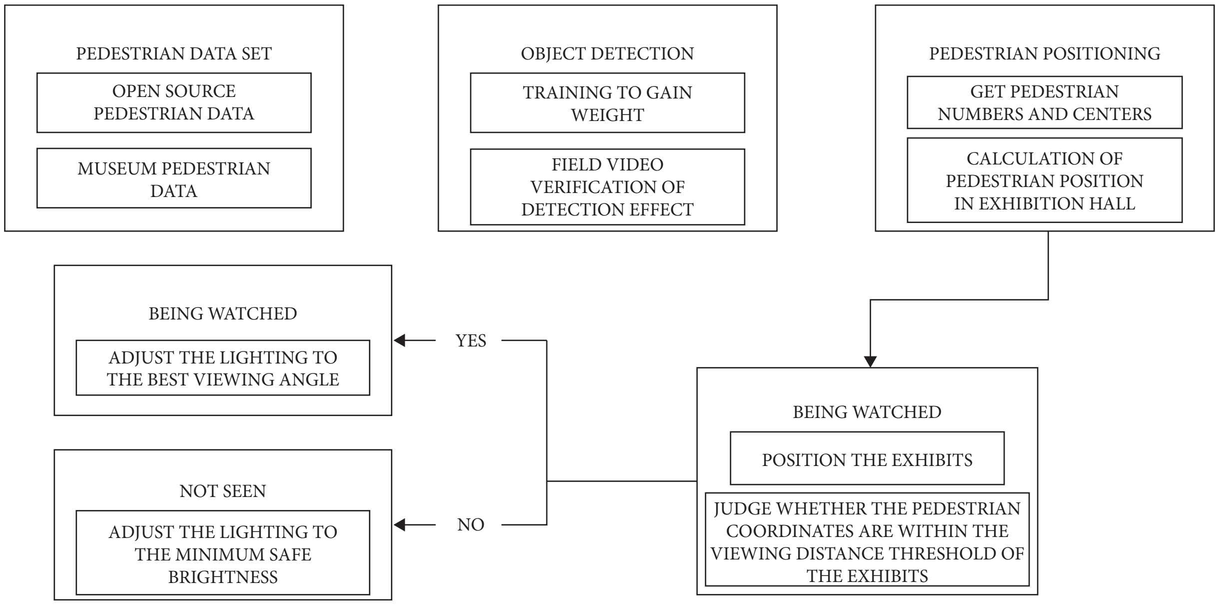

Figure 6: Lighting control system based on behavior detection.

Figure 7: Museum pedestrian dataset production.

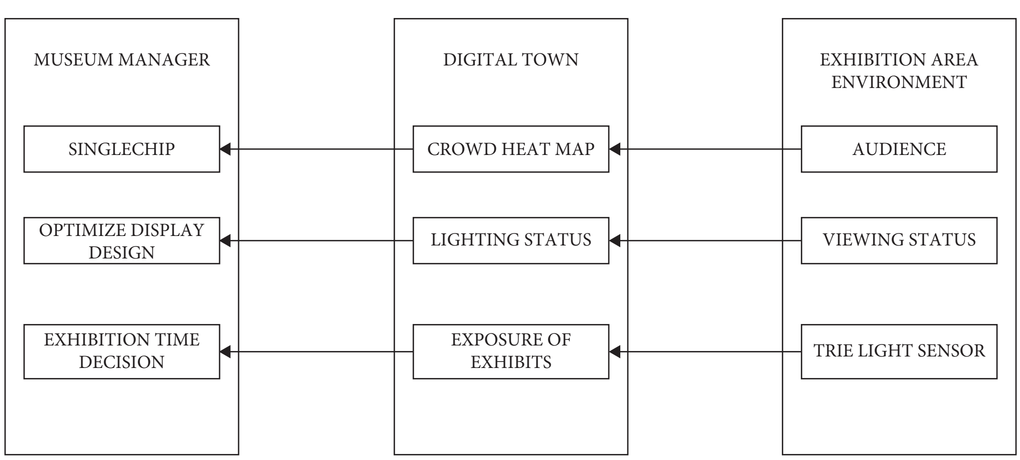

Figure 8: Twin digital platform.

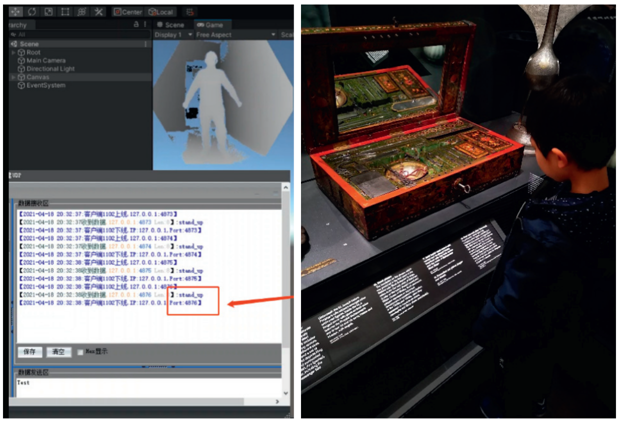

Figure 9: Recognition of the standing posture.

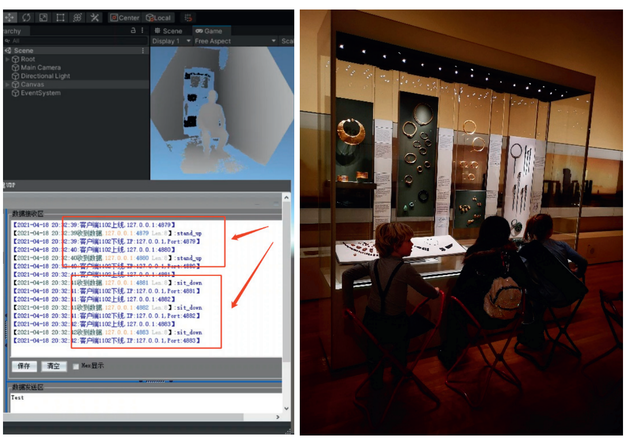

Figure 10: Recognition of the sitting posture.

transmits RGB and depth data to the aforementioned server in the venue through the optical fiber.

Kinect DK device based on Microsoft can track multiple human bodies at the same time. Through the development of body tracking SDK, the data of each human body in the field of vision can be obtained, including the time-dependent sequence between each picture and the moving bones and the number of human bodies detected in each picture. Based on this, we can determine whether there is an audience near the booth.

After confirming the audience is close to the exhibits, it is necessary to judge whether they are in the viewing position. The most important part of each human body data is the joint data. Joint position and orientation are estimated based on the depth learning framework of the global depth sensor. The unit of position is mm, and the direction is expressed by Euler angle. The position and direction of each joint constitute its own joint coordinate system, and all joint coordinate systems are absolute coordinates relative to the 3D coordinate system of deep camera data.

If the light source is too close to the object, the surface of the object will reflect high-reflection light. If the angle of the light is too vertical, the projected shadow will become longer and the edges will become sharper. When the smallpox part uses a translucent light source, the place where it produces the strongest reflected light is most likely the overhead part of the visitor. If the visitor looks directly at the showcase, the reflected light will enter the viewer's view (see Figure 9).

After realizing the accurate recognition of the posture of "looking down," we can determine whether an exhibit is in the state of being watched. When the exhibits are being viewed, the background adjusts the local lighting of the exhibits to the best viewing illumination; when the exhibit is not viewed, the background adjusts the local lighting of the exhibit to the lowest detectable illumination (see Figure 10).

5. Conclusion

Based on the field investigation of museum lighting design, this paper finds some problems and shows how target detection technology, digital twin technology, and human-computer interaction based on motion capture technology are applied to museum lighting design from the perspective of exhibition exposure protection. The intelligent lighting system designed in this paper can ensure the exhibition experience and reduce the unnecessary exposure of museum exhibits. At present, there are still limitations in our research work and design scheme. For example, we have not studied a more detailed light radiation control scheme for specific exhibits and only protect them at the actual exposure quantization level, which is also a research vacancy in the world. In addition, as the workload of the project team is focused on the theoretical research and design of the intelligent lighting system, no equipment test is installed on the spot, and there are bound to be many detailed problems in the application process of large exhibition space, complex structure, and crowded exhibition scenes, which will be discussed in the follow-up research process. The human-computer interaction scheme based on motion capture technology studied in this paper can be further studied in the future in order to become a set of low-cost and portable motion capture schemes. Motion capture has great potential in game animation, film and television animation, virtual image, and other fields. However, in the current commonly used motion capture schemes, the cost of equipment is very high, and the implementation site is limited. The author will continue to study on the basis of the existing achievements in this paper in order to form a more mature human-computer interaction scheme and motion capture scheme [25].

Data Availability

The datasets used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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Research Article

Service Composition Recommendation Method Based on Recurrent Neural Network and Naive Bayes

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Due to the lack of domain and interface knowledge, it is difficult for users to create suitable service processes according to their needs. Thus, the paper puts forward a new service composition recommendation method. The method is composed of two steps: the first step is service component recommendation based on recurrent neural network (RNN). When a user selects a service component, the RNN algorithm is exploited to recommend other matched services to the user, aiding the completion of a service composition. The second step is service composition recommendation based on Naive Bayes. When the user completes a service composition, considering the diversity of user interests, the Bayesian classifier is used to model their interests, and other service compositions that satisfy the user interests are recommended to the user. Experiments show that the proposed method can accurately recommend relevant service components and service compositions to users.

1. Introduction

With the rapid development of Web 2.0, users gradually participate in the creation of web content. However, it is becoming more and more difficult to meet users' complex needs with the single service. Thus, users begin to combine different services for the generation of their own service composition [1–3]. Service compositions refer to several services in a certain logical order to form an integrated application. For example, IFTTT (If This Then That) was used to customize smog SMS. IFTTT has started a new trend, shifting users from creating content to creating service composition. The traditional service system, however, is too complicated and has poor scalability. It is difficult for users to combine services. Therefore, the lightweight WEB-API has become the future direction of service composition, owing to its easy access, extensibility, and easy development.

The user-oriented lightweight service composition allows users to drag and drop service components on a lightweight service composition platform to generate a new service sequence. It can thus fulfill users' individual needs. Generally speaking, the platform tools of lightweight service composition can support graphical components encapsulated by third parties, such as RSS/Atom feeds, web services, and various programming APIs (Google Maps, Flickr). Users can create service compositions through a visual operation interface without programming skills. Both the industry and the academia have shown great interest in this user-oriented lightweight service composition method.

Although the service composition tools are recognized by users, they still need strategic guidelines when combining lightweight services [4]. These guidelines include initial user guidance and user interest extraction. For the initial user guidance, at the beginning phase of the service selection, when a user selects a service component, other service components that effectively associate with the selected service should also be added in the recommendation list and be recommended to the user because of their potential unknown interests. For user interest extraction, owing to the diversity of user interests, the current user interest scenario should be modelled according to the user's selection. Other service compositions similar to the user interests should be recommended to the user.

In view of the above reasons, the paper puts forward a service composition recommendation method based on recurrent neural network and Naive Bayes. The method is divided into two stages: (1) When a user's initial interests are unknown, according to the user's selection, the method firstly recommends n service components with the highest correlation to the user by the RNN algorithm. (2) When the user completes a service composition, considering the diversity of their interests, the Bayesian classifier is used to model these interests, and other service compositions suitable for the user interests are recommended to the user. In the current research, the RNN algorithm recommends related services to users, which is likely to alleviate the problem of service mismatch. The Naive Bayes algorithm provides users with other service compositions that can satisfy their interests. It not only can meet the diversity of user interests but also can create excellent service compositions in the template with reused library. Experiments show that the proposed method is able to accurately recommend service components and service compositions to users.

2. Related Works

Previous researchers mainly utilized the topic model to obtain the latent topics for the improvement of the recommendation accuracy, for instance, the Latent Dirichlet Allocation (LDA) [5]. However the training of topic model was time-consuming. Subsequently, the matrix factorization was widely applied in service recommendations [6]. As the matrix factorization was not suitable for general prediction tasks, a general predictor method named Factorization Machines (FM) [7] was proposed. By exploiting Factorization Machines, Cao et al. [8] proposed the Self-Organization Map-Based functionality clustering algorithm and the Deep Factorization Machine-Based quality prediction algorithm to recommend API services. In addition, to solve the sparsity problem of historical interactions, Cao et al. [9] used topic models to extract the relationships between mashups and to model the latent topics. Although the above methods had generated several satisfactory results, traditional service recommendation approaches usually overlooked the dynamic nature of usage pattern. Therefore, it is suggested by Bai et al. [10] to incorporate both the textual content and the historical usage to build latent vector models for service recommendation. Meanwhile, to address the cold-start problem, Ma et al. [11] proposed learning the interaction information between candidate services and mashups based on the content and the history. Then, according to interaction vectors, a multiple layer perceptron was used to predict the rank of candidate services. Through the user's historical service access records, Gao et al. [12] utilized a PLSA-based semantic analysis model to capture the user's interests and to recommend the services that meet the user's preference.

In recent years, a few researchers have begun to pay attention to service recommendation from the perspective of Quality of Service (QoS) [9,13–19]. By focusing on the network resource consumption, Zhou et al. [13] used an integer nonlinear programming to solve microservice mashup problems, and an approximation algorithm was designed to solve the NP-hard problem. Xia et al. [14] offered to determine each service's virtual cost according to the service's attributes and the user's preference. As a result, the service composition with the least total virtual cost was recommended to users. In addition, in terms of service function, by weighing the relationship between maximizing service cousage, maximizing functional diversity, and maximizing functional matching, Almarimi et al. [20] provided the nondominated sorting genetic algorithm to extract an optimal set to create a mashup. Shin et al. [21] proposed a service composition method based on functional semantics, and Shi et al. [22] employed a Long Short-Term Memory- (LSTM-) based method with a functional attention mechanism and a contextual attention mechanism to recommend services. In terms of semantic relevance, Ge et al.[23] suggested to effectively use the existing service composition and semantic association to expand the scope of service recommendation. In the research of Duan et al. [24], the integration of the probabilistic matrix factorization (PMF) model and the probabilistic latent semantic index (PLSI) model were adopted to recommend services to users. In the present study, the PLSI model was used to train user access records. By mining historical execution trajectories, He et al. [25] discovered potential behavior patterns based on the context and user characteristics. And context-related and preference-related user activity selection probability models were established. This potentially supported the construction and the recommendation of optimized personalized mashup.

In summary, when a user clicks on the service "Flickr," combining the user has clicked the service "Facebook" before, it can thus recommend other services linked to the sequence Facebook- > Flickr. After the user finishes a service process, because of the diversity of user interests, it is necessary to recommend other service processes that are of potential interests. However, most schemes in previous studies only focus on one point, weakening the user's experience. In addition, the service component recommendation based on association rules ignores the relevance between word orders; thereby, it has a relatively low recommendation accuracy. The service composition recommendation based on QoS mainly focuses on the nonfunctional needs of users. In the Mobile Internet and the 5G era, users, however, pay more attention to their functional requirements. Therefore, this paper proposes a service composition recommendation method based on the RNN and Naive Bayes. The RNN is used to ensure the relevance between word orders. Naive Bayes is adopted to identify users' potential interests according to the component function and provides users with excellent service processes in the template library.

3. Algorithm Description

3.1. Service Component Recommendation Based on Recurrent Neural Network. In this section, service compositions are first sent to RNN for training. The training is divided into two phases: forward propagation and back propagation. Then the error losses of the output layers at different times are obtained through forward propagation. Subsequently, according to the cross entropy of error losses, weight increments $\nabla U, \nabla V, \nabla W$ are calculated through back propagation. Finally, the weights U, V, W are updated by a gradient descent method.

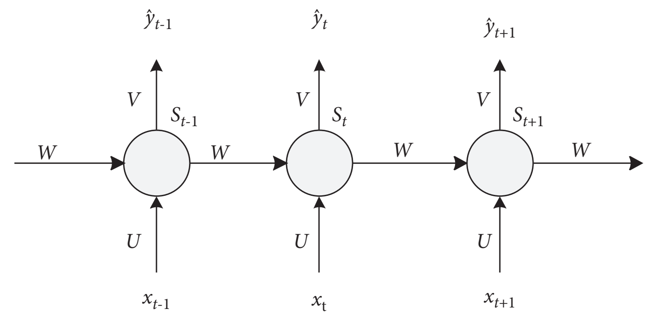

Figure 1: The forward propagation process of RNN.

3.1.1. Preprocessing of Service Process Call Records. To train a suitable RNN, it is needed to preprocess the service process call records as the input data and the predefined output data. Here, for each service composition in the training set, the last service component is deleted, and other service components are inserted into the list x_data as a list element. For each service composition, the first service component is deleted, and other service components as the corresponding list element are inserted into the list y_data. For example, if two service compositions are Facebook- > Flickr- > GoogleMaps and Time- > Weather- > Text, where - > represents the linked sequence between service components, then $x\_data =$ [["Facebook", "Flickr"], ["Time", "Weather"]], $y\_data =$ [["Flickr", "GoogleMasp"], and ["Weather", "Text"]]. Here x_data_j will be used as the input data of forward propagation, and y_data_j will be used as the predefined output data of back propagation. x_data_j and y_data_j need to be converted to a one-hot vector before training. In other words, there are L words in the dictionary; if the position of a service in the dictionary is j, then the service can be represented as an L-dimensional vector, where the j^{th} dimension is set to 1, and the remaining dimensions are all set to 0.

3.1.2. Forward Propagation. The forward propagation process of RNN is shown in Figure 1. Here U represents the weight between the input layer and the hidden layer. V represents the weight between the hidden layer and the output layer. W represents the weight of the adjacent hidden layers.

At time t, x_t is the input value, and s_t is the state in the hidden layer, which is related to the input value x_t and the state s_{t-1} of the previous hidden layer. The mathematical expression is $s_t = f(Ux_t + Ws_{t-1})$. f represents an activation function in the hidden layer. In the paper, $f = \tanh$.

$\hat{y}_t$ is the output value at time t. The mathematical expression is $\hat{y}_t = g(Vs_t)$. In the output layer, g represents an activation function. In the paper, $g() =$ softmax().

3.1.3. Back Propagation. RNN uses the back propagation to add up the error losses of the output layers at different times to obtain the total error loss E and then calculates the gradient of each weight U, V, W to obtain weight increments $\nabla U, \nabla V, \nabla W$ and finally employs a gradient descent method to update each weight U, V, W.

(1) Error Loss Function. For each time t, there will be an error loss e_t between the output value $\hat{y}_t$ of RNN and the predefined output value y_t. Assuming that the cross entropy is used as the error loss function, there is a total error loss $E = \sum_{t=1}^{N} e_t$, and $e_t = -\sum_{i=1}^{L} y_t(i) \ln \hat{y}_t(i)$, where N represents the length of x_data_j or y_data_j, L represents the length of the one-hot vector, and $x_t \in x\_data_j$, $y_t \in y\_data_j$.

(2) Gradient Calculation. For ∇V, V does not depend on the previous states; thus, it is relatively easy to obtain. However, for $\nabla W, \nabla U$, the chain derivation rule is needed to obtain them. The calculation process is as follows:

$$\begin{cases} \nabla U = \dfrac{\partial e_t}{\partial U} = \dfrac{\partial e_t}{\partial \hat{y}_t} \cdot \dfrac{\partial \hat{y}_t}{\partial s_t} \cdot \dfrac{\partial s_t}{\partial U} + \dfrac{\partial e_{t+1}}{\partial \hat{y}_{t+1}} \cdot \dfrac{\partial \hat{y}_{t+1}}{\partial s_{t+1}} \cdot \dfrac{\partial s_{t+1}}{\partial s_t} \cdot \dfrac{\partial s_t}{\partial U} \\ = \left(\dfrac{\partial e_t}{\partial \hat{y}_t} \cdot \dfrac{\partial \hat{y}_t}{\partial s_t} + \dfrac{\partial e_{t+1}}{\partial \hat{y}_{t+1}} \cdot \dfrac{\partial \hat{y}_{t+1}}{\partial s_{t+1}} \cdot \dfrac{\partial s_{t+1}}{\partial s_t} \right) \cdot \dfrac{\partial s_t}{\partial U}, \\ \nabla V = \dfrac{\partial e_t}{\partial V} = \dfrac{\partial e_t}{\partial \hat{y}_t} \cdot \dfrac{\partial \hat{y}_t}{\partial V}, \\ \nabla W = \dfrac{\partial e_t}{\partial W} = \dfrac{\partial e_t}{\partial \hat{y}_t} \cdot \dfrac{\partial \hat{y}_t}{\partial s_t} \cdot \dfrac{\partial s_t}{\partial W} + \dfrac{\partial e_{t+1}}{\partial \hat{y}_{t+1}} \cdot \dfrac{\partial \hat{y}_{t+1}}{\partial s_{t+1}} \cdot \dfrac{\partial s_{t+1}}{\partial s_t} \cdot \dfrac{\partial s_t}{\partial W} \\ = \left(\dfrac{\partial e_t}{\partial \hat{y}_t} \cdot \dfrac{\partial \hat{y}_t}{\partial s_t} + \dfrac{\partial e_{t+1}}{\partial \hat{y}_{t+1}} \cdot \dfrac{\partial \hat{y}_{t+1}}{\partial s_{t+1}} \cdot \dfrac{\partial s_{t+1}}{\partial s_t} \right) \cdot \dfrac{\partial s_t}{\partial W}. \end{cases} \tag{1}$$

Assuming the error variation of the hidden layer $\delta_t^h = \partial e_t / \partial \hat{y}_t \cdot \partial \hat{y}_t / \partial s_t + \partial e_{t+1} / \partial \hat{y}_{t+1} \cdot \partial \hat{y}_{t+1} / \partial s_{t+1} \cdot \partial s_{t+1} / \partial s_t$ and the error variation of the output layer $\delta_t^o = \partial e_t / \partial \hat{y}_t$, $\nabla U, \nabla V, \nabla W$ can be expressed as follows:

$$\begin{cases} \nabla U = \dfrac{\partial e_t}{\partial U} = \dfrac{\partial e_t}{\partial \hat{y}_t} \cdot \dfrac{\partial \hat{y}_t}{\partial s_t} \cdot \dfrac{\partial s_t}{\partial U} + \dfrac{\partial e_{t+1}}{\partial \hat{y}_{t+1}} \cdot \dfrac{\partial \hat{y}_{t+1}}{\partial s_{t+1}} \cdot \dfrac{\partial s_{t+1}}{\partial s_t} \cdot \dfrac{\partial s_t}{\partial U} \\ = \delta_t^h \cdot \dfrac{\partial s_t}{\partial U}, \\ \nabla V = \dfrac{\partial e_t}{\partial V} \\ = \delta_t^o \cdot \dfrac{\partial \hat{y}_t}{\partial V}, \\ \nabla W = \dfrac{\partial e_t}{\partial W} = \dfrac{\partial e_t}{\partial \hat{y}_t} \cdot \dfrac{\partial \hat{y}_t}{\partial s_t} \cdot \dfrac{\partial s_t}{\partial W} + \dfrac{\partial e_{t+1}}{\partial \hat{y}_{t+1}} \cdot \dfrac{\partial \hat{y}_{t+1}}{\partial s_{t+1}} \cdot \dfrac{\partial s_{t+1}}{\partial s_t} \cdot \dfrac{\partial s_t}{\partial W} \\ = \delta_t^h \cdot \dfrac{\partial s_t}{\partial W}. \end{cases} \tag{2}$$

In RNN, the calculation of back propagation is from the back to the front. At each moment, weight increments $\nabla U, \nabla V, \nabla W$ are updated as follows:

$$\begin{cases} \Delta U = \Delta U + \delta_t^h \cdot \dfrac{\partial s_t}{\partial U}, \\ \Delta V = \Delta V + \delta_t^o \cdot \dfrac{\partial \hat{y}_t}{\partial V}, \\ \Delta W = \Delta W + \delta_t^h \cdot \dfrac{\partial s_t}{\partial W}. \end{cases} \tag{3}$$

(3) Weight Update. When the training of a service composition is completed, the RNN uses a gradient descent method to update U, V, W along the negative gradient direction. The updated process is as follows:

$$\begin{cases} U = U - lr * \Delta U, \\ V = V - lr * \Delta V, \\ W = W - lr * \Delta W. \end{cases} \tag{4}$$

Here the initial U, V, W are randomly generated. lr is the step length of the gradient descent method.

After the update of U, V, W is completed, the loop is repeated until the error loss E reaches the threshold. At this time, the weights U, V, W are used to predict the output results according to the input data.

3.1.4. Service Components Recommendation. When users select a service component, the service component is sent to the RNN. It uses the weights U, V, W obtained in Section 3.1.3 to compute the following prediction services and then sends the top n prediction services to the recommendation list and posts them to users.

3.2. Service Composition Recommendation Based on Naive Bayes. It is noted that service components selected by users need to be further reduced through the information gain, and then the Naive Bayes classifier is exploited to extract user interests based on the reduced service component set. Finally, similar service compositions are recommended to the user according to their interests. Bayesian can quickly and efficiently identify the user's interest according to several service components clicked by the user; and those with similar interest in the user template library can directly match the common components clicked by the user.

3.2.1. Information Gain. After users finish a service composition, we need to determine user interests based on this service composition. To decrease the interference of noncritical service components, the information gain algorithm is used to reduce the service component set. The gain value *IG(s)* of each service component in the service composition can be calculated. The service components are sorted by the gain value *IG(s)*, and the first n service components are regarded as the reduced service component set.

The process is as follows:

(1) The entropy of each service component SC_j in the service composition SC is calculated, which is $H(SC_j|SC)$.
(2) The entropy without this service component SC_j in the service composition SC is calculated, which is $H(SC_j|\overline{SC})$.
(3) The difference between the entropy $H(SC_j|SC)$ and the entropy $H(SC_j|\overline{SC})$ is the classification gain value of this service component, which is $IG(SC_j)$, as shown in the following formula:

$$\begin{aligned} IG(SC_j) &= H(SC_j|SC) - H(SC_j|\overline{SC}) \\ &= -\sum_{i=1}^{n} P(c_i).\ \log_2 P(c_i) + \sum_{i=1}^{n} P(c_i|SC_j)\log_2 P(c_i|SC_j) + \sum_{i=1}^{n} P(c_i|\overline{SC_j})\log_2 P(c_i|\overline{SC_j}), \\ P(c_i|SC_j) &= \frac{n(SC_j|c_i)}{n(c_i)}, \\ P(c_i|\overline{SC_j}) &= \frac{n(\overline{SC_j}|c_i)}{n(c_i)}. \end{aligned} \tag{5}$$

Here $P(c_i|SC_j)$ represents the probability of the service component SC_j belonging to interest c_i. $P(c_i|\overline{SC_j})$ denotes the probability of the service component SC_j not belonging to interest c_i. $n(SC_j|c_i)$ means the number of service compositions including SC_j in interest c_i. $n(\overline{SC_j}|c_i)$ means the number of service compositions excluding SC_j in interest c_i. $n(c_i)$ is the number of service compositions in interest c_i. $P(c_i)$ represents the proportion of services compositions belonging to interest c_i in all services compositions.

(4) The service components are sorted according to the classification gain value, and the first n service components form a reduced service component set.

3.2.2. User Interest Modeling. According to the reduced service component set, the Naive Bayes classifier is exploited to determine the user interests.

The process is specified as follows:

(1) As discussed in Section 3.2.1, the probability of the reduced service component set belonging to each interest category is calculated by the Naive Bayes classifier, which is $P(c_i|SC)$. According to the Bayesian formula, $P(c_i|SC) = P(c_i|SC_1, SC_2, \ldots, SC_n) \propto P(SC_1, SC_2, \ldots, SC_n|c_i)P(c_i)$. Assuming that $SC_1, SC_2, \ldots, SC_n$ are independent, $P(SC_1, SC_2, \ldots, SC_n|c_i) = \prod_{j=1}^{n} P(SC_j|c_i)$. As shown in formula (6), SC represents the sequence of the reduced service components ($SC_1, SC_2, \ldots, SC_n$).

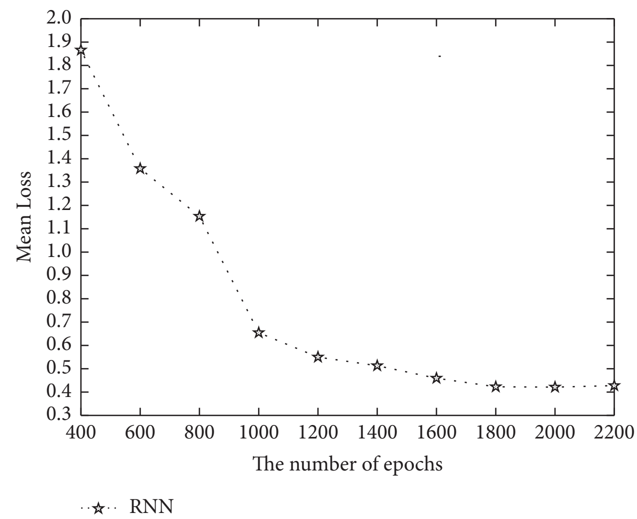

Figure 2: The number of RNN's iterations.

$$P(c_i|SC) = P(c_i|SC_1, SC_2, \ldots, SC_n) \propto P(SC_1, SC_2, \ldots, SC_n|c_i)P(c_i),$$
$$P(SC_1, SC_2, \ldots, SC_n|c_i) = \prod_{j=1}^{n} P(SC_j|c_i). \quad (6)$$

(2) According to formula (6), $P(c_i|SC) \propto P(c_i)\prod_{j=1}^{n} P(SC_j|c_i)$. This paper selects the interest category with the highest probability as the user interest; therefore, formula (7) is feasible.

$$\arg\max P(c_i|SC) \propto \arg\max\left[P(c_i)\prod_{j=1}^{n} P(SC_j|c_i)\right]. \quad (7)$$

3.2.3. Service Compositions Recommendation. According to the reduced service component set, the Naive Bayes classifier is exploited to determine the user interests.

The N-gram distance is used to compute the distance between different service compositions, and the service compositions are recommended to the user based on the similarities from high to low.

The process is specified as follows:

(1) In the service composition data set, service compositions consistent with the user interests are selected.

(2) The N-gram distance is used to compute the distance between the selected service compositions and the reduced service component set. Depending on the distance, service compositions that are most similar to the reduced service component set are recommended, as shown in the following formula:

$$\text{distance}(SC^p, SC^q) = GN(SC^p) + GN(SC^q) - 2 \times |GN(SC^p) \cap GN(SC^q)|. \quad (8)$$

(3) Here, $GN(SC^p)$ denotes the number of service components in service composition SC^p. $GN(SC^q)$ denotes the number of service components in service composition SC^q. $GN(SC_l) \cap GN(SC_p)$ is the number of the same service components in two service compositions. The similarity between two service compositions increases with the decrease in their distance.

4. Experiments

Experiments in this paper attempt to verify the effectiveness of RNN and Naive Bayes. Section 4.1 describes the data set used in Sections 3.1 and 3.2. Section 4.2 depicts the linked prediction performance of RNN, including the number of RNN's iterations, the precision, and the time comparison with the traditional algorithms (Apriori and N-gram).

Section 4.3 reports the classification performance of Naive Bayes. Section 4.4 explores the recommendation performance of N-gram distance.

4.1. Dataset. This paper uses service process call records and the service composition data set from the ProgrammableWeb website to conduct experiments. Service process call records include 20035 users' records. To improve the precision of experiments, the paper eliminates records of inactive users. In particular, users who call service processes less than 3 are regarded as inactive users; thus, there are 11730 service process call records used for our experiments. The service composition data set includes 13,082 service processes, and there are 24 types of the classification labels of service processes.

4.2. The Linked Prediction Performance of RNN

4.2.1. The Number of Iterations. The mean loss is given as follows:

$$\text{mean loss} = \frac{\sum E}{\text{the number of iterations}}. \quad (9)$$

This paper adopts the free-running mode for training. The training results are shown in Figure 2 and the mean loss is shown in formula (9). Here E represents the loss of each round iteration. It can be seen that as the number of iterations increases, the mean loss of each epoch gradually decreases. When the number of iterations reaches 2000, the convergence of the RNN algorithm is achieved.

4.2.2. Algorithm Comparison. This section compares the RNN algorithm with the traditional Apriori algorithm and the N-gram algorithm. The Apriori algorithm is a common association rule algorithm in data mining, mainly used in recommendation systems. The N-gram algorithm is also used in recommendation systems, but it can effectively reduce the recommendation space through learning the context. The comparison results demonstrate the feasibility of the RNN algorithm.

(1) Comparison of the Recommendation Precision between RNN(1), Apriori(1), and N-Gram(1). RNN(1) represents the recommendation algorithm RNN after the user calls a service component. Apriori(1) represents the recommendation algorithm Apriori after the user calls a service component. N-gram(1) represents the recommendation algorithm N-gram after the user calls a service component.

$$\text{precision} = \frac{L\left(\text{Rec}\left(sc_1 \ldots sc_i\right) \cap sc_{i+1}\right)}{L\left(\text{Rec}\left(sc_1 \ldots sc_i\right)\right)}. \quad (10)$$

As shown in Figure 3, the ordinate represents the recommendation precision of service components, as shown in formula (10). Here, $L(\text{Rec}(sc_1 \ldots sc_i))$ represents the number of recommended service components for the called service component sequence $sc_1 \ldots sc_i$. sc_{i+1} represents the actually linked service component for the called service component sequence $sc_1 \ldots sc_i$. $\cap$ represents the intersection. $L(\text{Rec}(sc_1 \ldots sc_i) \cap sc_{i+1})$ equals 0 or 1. The abscissa Top-P represents the number of service components required to be recommended. In practice, due to the control of the predefined threshold T, $L(\text{Rec}(sc_1 \ldots sc_i)) \leq \text{Top} - P$, where $T = 0.42$. As can be seen, the precision of RNN(1) is superior to those of Apriori(1) and N-gram(1). When the Top-P is 5, RNN(1) presents the best performance. At this time, the precision of RNN(1) is 0.41, higher than 0.17 of Apriori(1) and 0.24 of N-gram(1). This is because the RNN and the N-gram can learn the linked relationships between service components through training, while Apriori can only learn the correlations between service components and cannot capture the linked order between service components. Meanwhile, due to the limitation of the Markov model, the RNN has shown superior context learning effects than the N-gram.

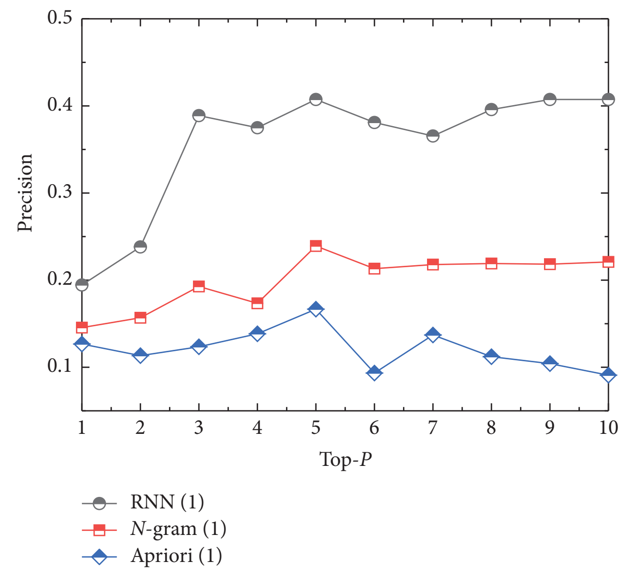

Figure 3: Comparison of the recommendation precision between RNN(1), Apriori(1), and (N)-gram(1).

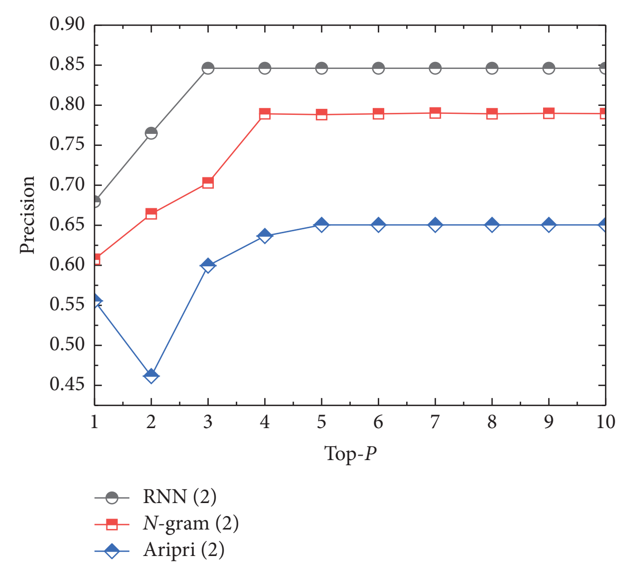

Figure 4: Comparison of the recommendation precision between RNN(2), Apriori(2), and (N)-gram(2).

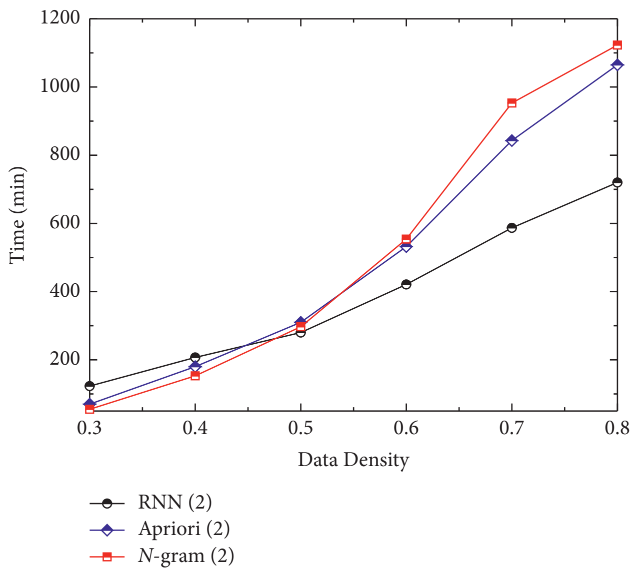

Figure 5: Comparison of the training time between RNN(2), Apriori(2), and (*N*)-gram(2).

(2) Comparison of the Recommendation Precision between RNN(2), Apriori(2), and (N)-Gram(2). As shown in Figure 4, RNN(2) represents the recommendation algorithm RNN after the user calls two components. Apriori(2) represents the recommendation algorithm Apriori after the user calls two components. *N*-gram(2) represents the recommendation algorithm *N*-gram after the user calls two components. When the user's initial selection of service components is greater than 1, the precision of RNN(2) is still superior to those of Apriori(2) and *N*-gram(2). When the Top-*P* is 5, the recommendation precision of RNN(2) is 0.85. The recommendation precision of Apriori(2) is 0.65. The recommendation precision of *N*-gram(2) is 0.79. At this time, the recommendation precisions of RNN(2), Apriori(2), and *N*-gram(2) are higher than those of RNN(1), Apriori(1), and *N*-gram(1). This is mainly because when the user selects more initial component sequences, there are fewer subsequently related service components, and the recommendation precision becomes higher.

(3) Comparison of Training Time. As shown in Figure 5, when the training data is small, the training times of the Apriori(2) algorithm and the *N*-gram(2) algorithm are lesser than that of the RNN(2) algorithm. But as the training data increases, the amount of data processed by the Apriori(2) algorithm and the *N*-gram(2) algorithm will increase exponentially. The training time of RNN(2) is lesser than those of Apriori(2) and *N*-gram(2). When the data density is 80%, it costs RNN(2) 720 minutes to train, while Apriori(2) takes 1065 minutes and *N*-gram(2) takes 1123 minutes.

4.3. The Classification Performance of Naive Bayes. As shown in Figure 6, precision% (classfication) refers to the precision of classification prediction through the service composition data set. The predicted label is compared with the real label, and finally the classification precision of the algorithm is obtained. As can be seen, with the increase in the training data, the

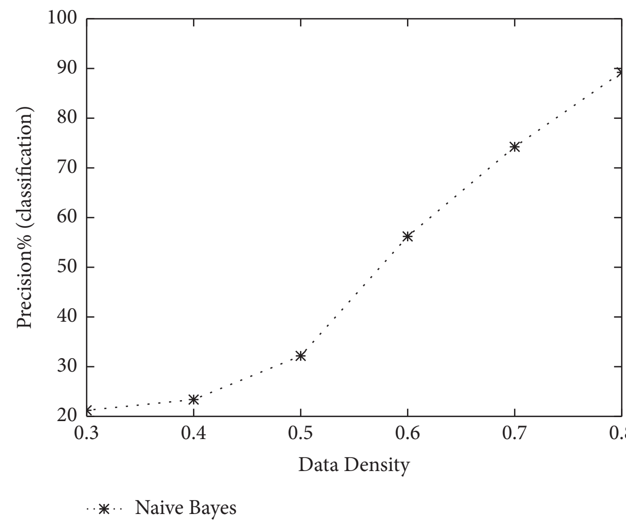

Figure 6: The classification performance of Naive Bayes.

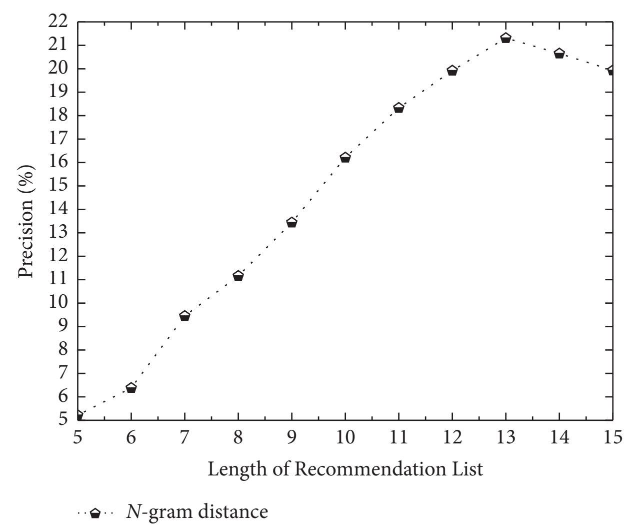

Figure 7: The recommendation performance of (*N*)-gram distance.

recommendation precision becomes higher. When the density of training data is 80% and that of the test data is 20%, the classification precision of Naive Bayes reaches 89.1%.

4.4. The Recommendation Performance of N-Gram Distance. Figure 7 analyzes the recommendation performance of *N*-gram distance. As the length of the recommendation list increases, the recommendation precision first increases and then decreases. When the length is 13, the recommendation performance is the optimal. At this time, the recommendation precision is 21.3%.

5. Conclusions

In order to optimize the assistance to users in their decision-making, this paper proposes a service composition recommendation method based on the RNN and Naive Bayes. This method has the following contributions:

(1) Different from traditional algorithms, this paper uses the context learning to reduce the recommendation space and provides users with more accurate service-linked components.

(2) To fulfill the diversity of user interests, this paper adopts the interest modeling to recommend other service processes that meet users' current interests. This can effectively promote the reuse of the template library.

It is yet worth noting that the interest modeling of Naive Bayes does not take the semantic similarity into consideration. As a result, future research would consider using the semantic analysis to model user interests.

Data Availability

The data included in this paper are available without any restriction.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

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Research Article

ARIMA Model-Based Fire Rescue Prediction

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In recent years, urban buildings have become taller, occupying more and more areas, frequent fires, and increasingly difficult fire rescue tasks. Predicting fire risks in advance will help fire rescue work. Therefore, this paper proposes a fire risk prediction based on the ARIMA model. By analyzing the fire rescue data of a certain place from 2016 to 2020 and based on the data from January 1, 2016, to December 31, 2019, an ARIMA model for predicting the number of fire rescue polices was established. The data from January 1, 2020, to December 31, 2020, are used as the validation data set of the model to evaluate the accuracy and stability of the model. The results show that the ARIMA model can be better applied to fire rescue prediction and provides a scientific prediction method for the research of smart fire rescue work.

1. Introduction

With the rapid development of our country's economy, the environmental complexity has risen sharply, various accidents and disasters have occurred frequently, and safety risks have continued to increase. The challenges of fire prevention, control, firefighting, and rescue problems such as physical, underground engineering, and large chemical companies will be even more severe. Smart fire rescue is an important part of the construction of smart cities. It is necessary to actively apply new technologies such as artificial intelligence [1, 2], big data [3, 4], cloud computing, Internet of Things [5, 6], and geographic information to establish a smart fire rescue system [7,8] to realize the identification and early warning of disaster occurrence patterns and risks, real-time monitoring of disaster information, intelligent remote monitoring of firefighting facilities, intelligent deployment of rescuers, and so on to build an unbreakable line of fire safety defense for the construction of smart cities. At the same time, with the rapid expansion of the city, the number and density of urban buildings are growing at a high rate. The complex function and structure of modern urban buildings bring a great difficulty to fire control. Efficient and safe building fire emergency rescue is a problem that needs to be solved urgently. Although in the past many experts and scholars have paid attention to how to improve the city's fire emergency rescue capabilities, it is a pity that the iteration speed of fire emergency rescue methods is still far behind the development speed of urban buildings. At present, the fire department's assessment of unit fire risk still depends on the experience of firefighters, which has great subjective uncertainty. Therefore, it is necessary to adopt a more general scientific method to assess the risk of fire. At the same time, local fire departments have stored a large amount of relevant data in fire protection practice, including fire rescue data, fire inspection data, basic information data of related units, and urban building data. To deeply analyze the historical data of fire protection and obtain the information hidden behind the data through technical means, so as to support the accuracy of the desired target, it is necessary to use reasonable methods and tools to process the data. Machine learning technology is an efficient method to obtain effective information through data cleaning, reasonable feature construction, learning, and training from databases, texts, data warehouses, and other information bases.

The ARIMA model was proposed by American statistician Jenkins and British statistician box in the 1970s. The ARIMA model is mainly used in the short-term prediction of time series variables. The single time series value is unpredictable, but the overall time series value has a certain law. The ARIMA model expresses this rule in mathematical form to realize the short-term prediction of time series value.

To predict the fire risk more accurately, this paper proposes a fire risk prediction and analysis method based on the ARIMA model. The time series analysis method is used to observe the changing trend of the number of fire rescue in a certain interval, mine the rule from the data, and predict the number of fire rescue alarms in the future. The significance of our work is as follows. (1) This paper proposes a fire risk prediction and analysis method based on the ARIMA model. By analyzing the fire and rescue data of a certain place, an ARIMA model is established to predict the number of times of fire and rescue police. (2) The ARIMA model has a simple structure and few parameters, and only endogenous variables are needed to build a predictive model. The model predicts the number of times of fire and rescue police iteratively, which is conducive to better mining the factors that affect the number of fire rescue police and the evolution trajectory. (3) The results show that the ARIMA model can be better applied to fire rescue prediction and provides a scientific prediction method for the research of smart fire rescue work.

2. Introduction to Fire Risk Prediction and Analysis Methods

The ability to predict fire risk [9, 10] is an important aspect of smart fire rescue. Time series forecasting, neural network, and polynomial fitting are some of the most commonly used methods for predicting and analyzing fire risks. However, assessing such multivariate environmental disasters has always been difficult because modeling can be skewed by a variety of factors, including the quality and quantity of input parameters, the training process, and hyperparameter default settings.

2.1. Time Series Analysis. A time series is a collection of observations derived from the progression of time, which is essentially the dependence of adjacent observations. Analyzing time series data allows researchers to determine the system's internal evolution law, as well as observe and predict the system's future development trend [11]. For example, Qiu Jie et al. [12] used Landsat time series data and machine learning methods to conduct quantitative research on forest fires and postdisaster vegetation restoration in the Daxinganling area, drawing a forest distribution map 1987–2016 disturbances in the Daxinganling area using the vegetation change tracking (VCT) algorithm. The VCT Block separates the burning points from the disturbance patches using the vector machine (SVM) classifier and historical fire records. The results show that VCT's forest interference events have high spatial precision. Most years have between 70% and 86 percent spatial accuracy. The proposed VCT-SVM algorithm extracts annual fire patches with an overall accuracy rate of 92%. The RF algorithm's prediction accuracy is better than that of SVM and SMLR according to the verification results. Gao Natekar et al. [13] investigated the use of long- and short-term memory neural networks to predict the spread of forest fires. In the northern beaches of Sydney, Naderpour Mohsen et al. [14] proposed a spatial framework for quantifying the risk of forest fires. In order to maximize the impact of multilayer perceptrons on forests, 36 key indicators from various backgrounds, such as terrain, form, climate, man-made, social, and physical, were selected and used as input to the model. The model can be tailored to different parts of Australia and has fewer requirements for weighting procedure localization, enhancing adaptability and decision-making ability.

2.2. ARIMA Model. The modeling of the ARIMA model can be divided into the following four steps. First, the stationarity test is performed on the original sequence. If the test result is not stable, it is necessary to make the sequence meet the stationarity conditions through differential changes or other changes. Second, the model is determined by calculating the statistics describing the characteristics of the sequence, and the order of the model is determined by combining certain criterion. Third, the parameters of the model are estimated, such as by the least square method, and the rationality test is carried out. Finally, the diagnostic analysis is carried out, the data are predicted through the generated model, and the actual data are compared with it for the prediction accuracy determination test. If the parameters are not determined accurately, a new model is established again.

2.3. Polynomial Fitting. Polynomial fitting is to use a polynomial expansion to fit all observation points in an analysis area containing several analysis grid points to obtain the objective analysis field of the observation data, and the expansion coefficient is determined by least square fitting [15]. Mei Peng et al. [16] proposed a rapid loss assessment network analysis method (ANP) for high casualties fires, established a context index (SI) and outcome index (CI) network, and compared ANP and multiple logistic regression. The correct classification rate of the accident level is directly related to the multilayer perceptron network and the radial basis function network. The findings show that ANP excels at high and extreme levels, as well as when accident levels are taken into account. Weighted least squares polynomial fitting is used to generate meaningful extreme possibility results for decision-making reference, and it can be used to obtain the relationship between the context index (SI) and the outcome index (CI) of high-level and extreme HCFs. To investigate the impact of temperature on the frequency of fires in Changsha, Liu Dingli et al. [17] collected and processed 20,622 fire data as well as historical weather data in Changsha. Data mining reveals that the average daily fire frequency is lowest in the temperature range of 20 °C and 25 °C, which is likely due to the low power utilization rate. The lowest daily temperature predicts better performance than the highest daily temperature, according to polynomial fitting.

3. Fire Rescue Prediction Based on ARIMA Model

3.1. Data Sources. This paper uses the situation of fire rescue police in a certain place from 2016 to 2020 as the data source. The calculation process is based on the data of that place from January 1, 2016, to December 31, 2019, and the number of fire rescue police is established by month. Predictive model uses the data from January 1, 2020, to December 31, 2020, as the model's verification data set, evaluates the accuracy and stability of the model, and predicts the number of fire rescue alarms in each month of 2021. The situation of fire and rescue police from 2016 to 2020 is shown in Table 1.

3.2. The Proposed Modeling for Fire Rescue Prediction

3.2.1. The Procedure of ARIMA Model. In our study, we use the ARIMA model for fire rescue prediction. The prerequisite for the establishment of the ARIMA model is that the time series are required to have stationarity. It can be judged intuitively by making the original sequence diagram, and the stationarity of the sequence can also be verified by the inspection method. If the sequence is not stable, one can use data transformation or difference to make the data stable. Combined with the data stabilization processing, the autocorrelation (ACF) diagram and partial correlation (PACF) diagram are drawn for the sequences that meet the stability requirements after preprocessing, and the model is preliminarily identified and ranked according to the tail-cutting or tailing of the ACF diagram and PACF diagram. If the ACF graph is tailing and the PACF graph is tail-cutting, the AR(p) model is applicable, and the value of PACF tail-cutting is the p value. Otherwise, the MA(q) model is selected, and the tail-cutting value of the ACF graph is the q value. If both ACF and PACF graphs are tailed, one can consider the ARIMA(p, d, q) model. Generally, a method of gradually trying from low order to high order is adopted. The next step is the fitting of the ARIMA function. The optimal model is tested to see whether there is a correlation between residuals. Then, the optimal model is used to predict the historical data. Finally, the optimal model is used for prediction.

From the historical data in Table 1, it can be seen that in order to predict the number of fire rescue polices in 2021, a fitting relationship between the numbers of polices and time should be established.

At present, the classic time series forecasting models include the ARIMA model, regression model, time convolutional network, and gray model. We use the ARIMA algorithm in this study. The ARIMA algorithm is one of the main tools for linear time series forecasting [18]. It takes the time data sequence of the prediction object as a random sequence for difference and smoothing and then uses a mathematical model to approximate the sequence to predict the future value of the time sequence.

The ARIMA model is a time series combination model that combines the autoregressive process (AR) and the moving average process (MA), written as ARIMA (p, d, q). P is the lag order of the autoregressive process, d is the lag order of the time series, and q is the lag order of the moving average process. The linear equation is as follows:

$$x_i = c + \sum_{i=0}^{p} \phi_i x_{i-1} + \varepsilon_i + \sum_{i=0}^{q} \theta_i \varepsilon_{i-1}, \tag{1}$$

where x_i is a stationary variable, c is a constant, $\phi_i (\phi_i \neq 0)$ is the coefficient of the coefficient $x_{i-1}, x_{i-2}, \ldots, x_{i-p}$of the autoregressive lag term, and ε_i is the residual. It is assumed that the residual sequence is a Gaussian white noise sequence. θ_i $(\theta_i \neq 0)$ is the coefficient of the moving average lag term $\varepsilon_{i-1}, \varepsilon_{i-2}, \ldots, \varepsilon_{i-q}$.

3.2.2. Data Stability Analysis and Processing. Let $\{X_t\}$ be the time series data of the number of alarms. From the time series diagram (Figure 1), it can be seen that the values of each series fluctuate up and down along a straight line, but the fluctuation range is very irregular, so it is a nonstationary time series. First, $\{X_t\}$ is smoothed to obtain the stationary time series $\{Z_t\}$, the statistical characteristics of the sequence $\{Z_t\}$ are judged, and the stationary time series model required for the modeling sequence $\{Z_t\}$ is determined. By calculating the ACF and PACF of the time series $\{Z_t\}$, the time series model required for the modeling sequence $\{Z_t\}$ is determined. The ACF and PACF diagrams of the sequence $\{Z_t\}$ are shown in Figures 2 and 3.

It can be seen from Figure 3 that the ACF of the sequence $\{Z_t\}$ always fluctuates around zero, rather than tending to zero. The ACF of the sequence $\{Z_t\}$ does not have tail-cutting properties and has tailing properties. In Figure 3, the PACF value of the sequence $\{Z_t\}$ always fluctuates around the zero value; instead of tending to zero at a certain moment, it also has a tailing property. Both of these functions have tailing properties, which are consistent with the characteristics of the ARIMA model [19].

3.2.3. Significance Test of Model Order and Parameters. After completing the stationary sequence, since the nonstationary sequence becomes a stationary sequence after k-th difference is completed, it obeys the ARMA(p, q) model, so the order is determined. Commonly used methods of order determination include F-test order determination method, residual variance graph order determination method, and function criterion order determination method [20]. The function criterion order determination method is to determine the order of the model by defining a criterion function. At present, there are Akaike information criterion (AIC) guidelines and BIC guidelines in the mainstream. For the ARMA (n, m) model, the calculation equation of the AIC quasi-measurement function is as follows:

Table 1: The situation of fire rescue police from 2016 to 2020 (unit: times).

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2016	79	95	98	51	275	67	63	40	50	31	38	43
2017	58	28	44	14	148	87	23	42	49	33	65	68
2018	54	129	68	71	107	119	59	50	46	44	40	63
2019	67	76	73	44	138	146	72	30	41	26	25	36
2020	28	23	28	46	62	55	25	29	36	25	51	62

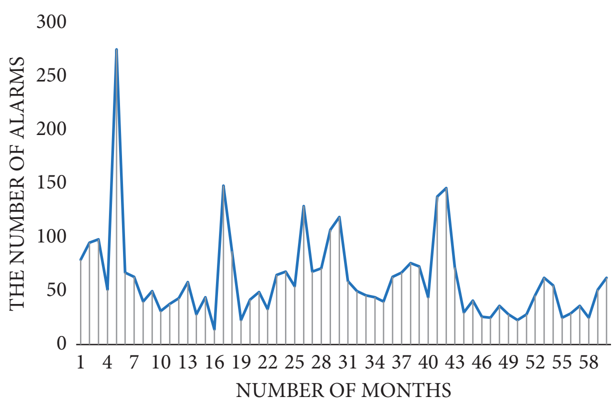

Figure 1: Time series chart distributed by month.

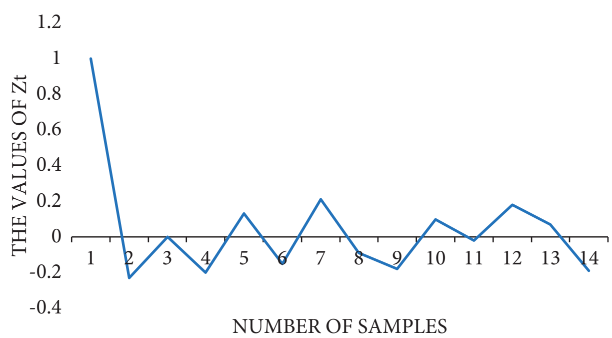

Figure 2: Autocorrelation function of sequence $\{Z_t\}$.

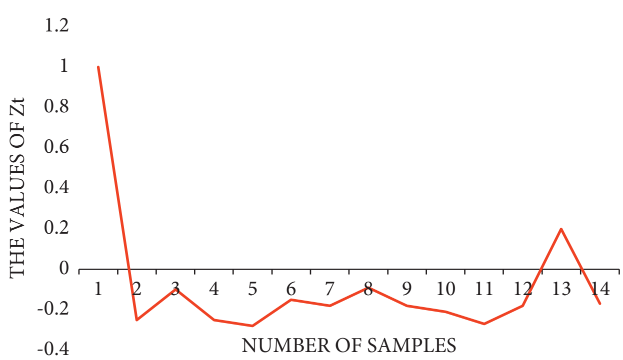

Figure 3: Partial autocorrelation function of sequence $\{Z_t\}$.

$$\mathrm{AIC}\,(n,m) = In\left(\sigma^2\right) + \frac{2\,(n+m)}{N}, \tag{2}$$

where n and m, respectively, model the autoregressive and moving average partial orders of ARMA, N is the number of sequence values, and σ^2 is the estimated value of noise variance in the model. The sequence $\{X_t\}$ is smoothed to get the sequence $\{Z_t\}$, and the order is determined by the AIC criterion. For a stationary time series $\{Z_t\}$, the order of ARMA (n,m) describing the sequence $\{Z_t\}$ is determined by comparing the AIC values of different models; that is, the autoregressive order n and the moving average order m in the model are determined. For a sequence $\{Z_t\}$ with 48 data, the corresponding model AIC value is calculated by the above formula. For the model ARMA (n,m), the upper and lower limits of n and m are determined, that is, the range of values for n and m. Generally, the lower limit is 1, and the upper limit is 1/10 of the number N of values in the sequence. Therefore, the lower limit of n and m is 1, and the upper limit is 5. It can be obtained that n and m have a total of $5{\times}5 = 25$ combinations of values, so there are a total of 25 AIC values. See Table 2 for details.

Through Matlab calculation, it is found that the minimum AIC value is AICmin = 6.7066. At this time, the corresponding orders n and m of the ARMA model are both 5. Therefore, the final selection model is ARMA (5, 5). According to the calculation, the number of differences $k = 1$.

3.3. ARIMA Model Analysis and Forecast. The application uses ARIMA (5,1,5) to model the sequence $\{Z_t\}$, and the fitting is shown in Figure 4.

In Figure 4, the trends of peaks and valleys fit more closely, so a rough forecast can be given. When evaluating the accuracy of the model using 12 data in 2020, an error analysis chart (Figure 5) and the error analysis table (Table 3) are listed.

Because there are many causes of accidents and disasters, the randomness is extremely large, so there is no complete law to follow. Therefore, the data given are very volatile, and the regularity is very weak. It is difficult to establish the prediction model itself. Therefore, when the ARIMA model gives data, the forecast in a certain few months may be very inaccurate (as in July 2020 in the above table). However, in general, the error has been small, the model is still more successful, and the accuracy is high.

In the stability check, several larger parameters were modified, and the excessively large parameters were reduced to a large extent. After changing the data, it is found that within the scope of 2020, the change in the fitted image is not

Table 2: AIC value.

No.	AIC	No.	AIC
1	7.4735	14	7.7080
2	7.5278	15	6.9001
3	7.5833	16	7.6174
4	7.6311	17	7.1971
5	6.9879	18	7.7448
6	7.5249	19	7.9597
7	7.5584	20	6.8510
8	7.6320	21	6.9208
9	7.6152	22	6.9572
10	7.2433	23	6.8995
11	7.6021	24	6.8006
12	7.5797	25	6.7066
13	7.6703		

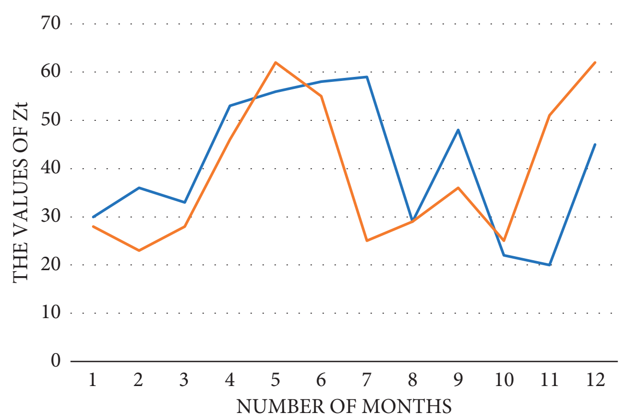

Figure 4: Schematic diagram of ARIMA(5,1,5) model fitting (blue line represents the actual value, and red line represents the predicted value).

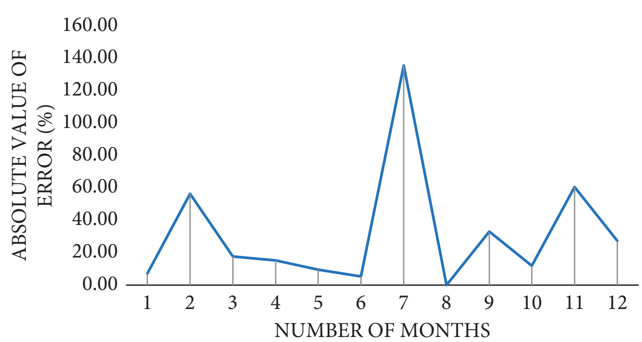

Figure 5: Error analysis.

Table 3: Error analysis.

Month in 2020	ARIMA	True	Absolute error (%)
Jan.	30	28	7.1
Feb.	36	23	56.5
Mar.	33	28	17.8
Apr.	53	46	15.2
May	56	62	9.6
Jun.	58	55	5.4
Jul.	59	25	136
Aug.	29	29	0
Sep.	48	36	33.2
Oct.	22	25	12
Nov.	20	51	60.7
Dec.	45	62	27.4

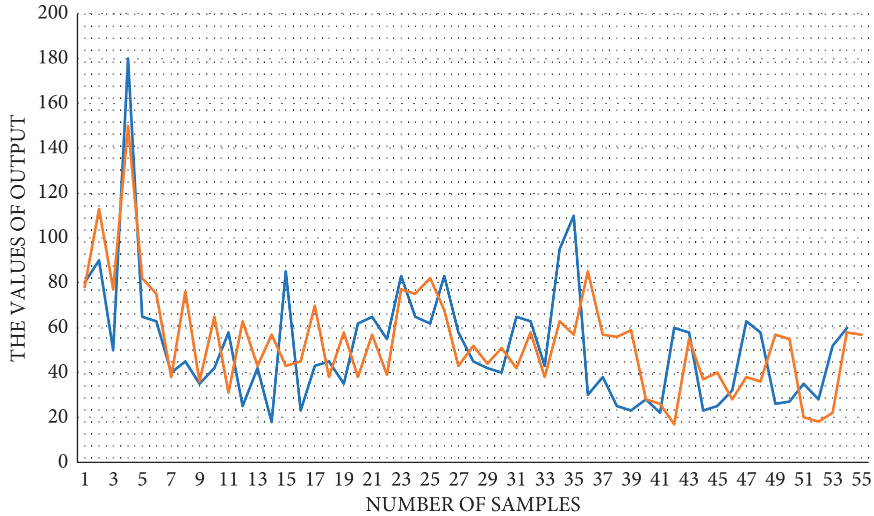

Figure 6: ARIMA model stability test results (blue line represents the samples from 2020, and red line represents the samples from 2021).

Table 4: Forecast of the number of fire and rescue police in each month of 2021.

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Forecast value/time	32	48	59	45	61	31	35	24	16	31	28	40

very large (see Figure 6). Therefore, this algorithm can guarantee certain stability in practical applications. When the parameters change within a certain range, the ARIMA algorithm can ensure that the sensitivity is not too high. The result will not change much. Table 4 shows the forecast results of the number of fire rescue police in each month of 2021.

4. Conclusion

This paper analyzes the fire rescue data from 2016 to 2020, uses the ARIMA algorithm to establish a predictive model of the number of fire rescue polices, uses the 2020 data for proofreading and analysis, and finally predicts the monthly number of police fires in 2021. This method only needs endogenous variables and not other exogenous variables and has strong operability and high accuracy. Through verification, the ARIMA model can better predict the number of fire rescue alarms. However, our ARIMA model also has several shortcomings. First, in our model, the future value of the sequence variable is assumed to satisfy the linear function relationship between the past observation value of the variable and the random error value. Since most time series contain nonlinearity, there are great limitations in the application of the ARIMA method in practical economic field. Second, the training of the ARIMA model requires enough historical data. These are the directions of our research work in the next stage.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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Research Article

Sentiment Analysis of Student Texts Using the CNN-BiGRU-AT Model

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For most current sentiment analysis models, it is difficult to capture the complex semantic and grammatical information in the text, and they are not fully applicable to the analysis of student sentiments. A novel student text sentiment analysis model using the convolutional neural network with the bidirectional gated recurrent unit and an attention mechanism, called CNN-BiGRU-AT model, is proposed. Firstly, the text is divided into multiple sentences, and the convolutional neural network (CNN) is used to extract n-gram information of different granularities from each sentence to construct a sentence-level feature representation. Then, the sentences are sequentially integrated through the bidirectional gated recurrent unit (BiGRU) to extract the contextual semantic information features of the text. Finally, an attention mechanism is added to the CNN-BiGRU model, and different learning weights are applied to the model by calculating the attention score. The top-down text features of "word-sentence-text" are input into the softmax classifier to realize sentiment classification. Based on the weibo_senti_100 k dataset, the proposed model is experimentally demonstrated. The results show that the accuracy rate and recall rate of its classification mostly exceed 0.9, and the $F1$ value is not lower than 0.8, which are better than the results of other models. The proposed model can provide a certain reference for the related students' text sentiment analysis research.

1. Introduction

In recent years, Internet social networking, especially mobile Internet social networking platforms, has rapidly emerged around the world, and online social platforms such as Facebook and Weibo have emerged. People tend to express their own opinions on events at online social media. The student group especially occupies a large proportion of the Internet social platform users [1]. People's evaluation often contains emotional tendencies. If you can collect these comment texts and analyze the emotional tendencies of the student groups, you can understand their emotional state for certain events and provide strong support for subsequent decision-making [2, 3]. With the continuous expansion of social network user groups, tens of thousands of data are generated per second on social platforms. However, it is extremely unrealistic to collect, query, analyze, and count this massive data information manually. Therefore, exploring an efficient and reliable way of student sentiment analysis has become a research focus [4].

With the development of statistics and computers, it has become possible for computer automation to quickly obtain text data generated by social platforms in real time. At the same time, the text can be counted, sorted, and analyzed [5]. At present, researchers have constructed many corpora for different text analysis tasks. Text segmentation is performed by the possibility of searching for words in the corpus [6]. After the computer performs basic word segmentation on these texts, its powerful computing power can be used to mine the emotions contained in the text. The existing methods for sentiment analysis research mainly include dictionary-based methods, traditional machine learning-based methods, and deep learning-based methods. The method based on the sentiment dictionary needs to construct the sentiment dictionary manually, which is not only time consuming but also laborious. Furthermore, the sentiment dictionary for a certain dataset may not be suitable for sentiment analysis tasks of other datasets [7, 8]. The traditional machine learning models usually need to manually or automatically select features, and then we can apply these machine learning models to classify the test data using these selected features [9, 10]. Not only does this method require a large amount of data as a basis, but also the characteristics of a certain dataset may not be adapted to other datasets. Deep learning technology can obtain the deep semantic and grammatical features of the text through the nonlinear learning of the neural network and achieve the purpose of automatically extracting features by the machine [11].

However, sentiment analysis has developed from the initial two categories of emotions to multiple categories of emotions. Most existing deep learning technologies cannot meet the requirements of high accuracy, and there is little research on student text sentiment analysis. To this end, a student text sentiment analysis model using the convolutional neural network-bidirectional gated recurrent unit-attention mechanism (CNN-BiGRU-AT) model is proposed. Compared with the traditional text sentiment analysis model, its innovations are summarized as follows:

(1) Existing research often uses hand-designed feature extraction methods to extract text features, which cannot capture the complex language phenomena in the text. The proposed model uses a combination of CNN and BiGRU to automatically learn the deep semantic information of the text from a large amount of data, which further ensures the accuracy of sentiment classification.

(2) Aiming at the problem that the feature matrix dimension of CNN-BiGRU model is too large and easy to overfit, the proposed model introduces an attention mechanism. Through a perception function, the target matrix and the weight matrix in the deep learning model are connected to strengthen the generalization ability of the model.

(3) The proposed CNN-BiGRU-AT model has solved the problem of accuracy degradation caused by sample randomness.

2. Related Research

Several major problems in text sentiment polarity analysis include the following: the establishment of word vectors, the establishment of associations between words, and the tendency classification of multiple sentiment dimensions in sentiment classification prediction [12]. Text sentiment analysis refers to the use of computers to automatically calculate and process human natural language texts, involving comprehensive problems in mathematics, statistics, and computational science. Its goal is to solve the problem of computer and text sentiment analysis in order to maximize the extraction of valuable information and achieve better human-computer interaction [13].

Text sentiment analysis is essentially symbolic, so people initially tried to use symbolic methods to express language, using logic-based, rule-based, and ontology-based methods [14]. According to whether a label set is required for training, text sentiment analysis algorithms can be divided into supervised learning and unsupervised learning. Supervised learning is a hot research topic, and a large number of high-quality models have emerged. Some models have also been put into practical application in the industry and have achieved good application results. Reference [15] created emotion label training data based on an emotion expression dictionary and used fastText for supervised learning to achieve accurate sentiment analysis and evaluation results. However, it did not consider the influence of different contexts on the emotional tendency of words. Reference [16] proposed a soft classification method to measure the probability of assigning information to each emotion category for factors such as blurred emotion boundaries, expression, and perceptual changes in automatic emotion detection. A supervised learning system is established to automatically classify emotions in text stream messages. However, the continuous field annotation of sentiment labels in the dataset configuration requires a high cost, which seriously affects the efficiency of analysis. Reference [17] proposed a multimodal emotion recognition system based on speech and facial images. The supervised learning methods k-nearest neighbor network and artificial neural network are used for emotion analysis, which can accurately extract facial expression features to complete emotion analysis. However, the cost of sentiment analysis is relatively high, and the analysis effect for students with strong arbitrariness is poor.

Unsupervised learning and semisupervised learning based on the two have always been the focus and difficulty of research. Recent research has increasingly focused on unsupervised and semisupervised learning algorithms. Core algorithms such as MLP, Support Vector Machine (SVM), and Logistic Regression are all trained on high-dimensional sparse feature vectors [18]. Reference [19] proposed a method of emotion recognition based on deep learning combined with semisupervised learning of long- and short-term memory. By using an appropriate amount of unlabeled datasets in parallel, the use of labeled datasets that require high training costs is minimized, and the analysis accuracy is guaranteed while the analysis efficiency is improved. However, the classification and recognition effect of some neutral words or irony words in the text data is poor. Reference [20] proposed a sentiment analysis model using sentiment dictionary and multichannel convolutional neural network. The input matrix of the emotion dictionary is constructed according to the emotion information, so that the model can learn the emotion information of the input sentence from the various feature representations in the training process. Then, the loss function is reconstructed to realize the semisupervised learning of the network, but the classification effect for colloquial and nonstandard expressions is not good. Reference [21] studied a mechanism in which the emotions in each pair of sentences conflict with each other. By observing the emotional orientation of each pair of sentences, we can identify the true value of the proposed conflict hypothesis and use the conflict matrix to identify the conflict emotion in the text and measure its characteristics. However, the use of unlabeled data is not enough, and the performance of unbalanced processing is poor. Reference [22] proposed a new attention-based label consistency (ALC) model. It makes good use of the relationship between different samples and smoothes the classes of unlabeled data by establishing a label imbalance ALC model. The model realizes more accurate text sentiment analysis. However, there is a certain degree of randomness in the text data submitted by students, and the accuracy of sentiment analysis needs to be improved.

Therefore, for the sentiment analysis of student texts, an analysis model based on CNN-BiGRU-AT is proposed. Under the premise of adapting to the randomness and nonstandardization of students' texts, it effectively takes into account the efficiency and accuracy of analysis.

3. Sentiment Classification Model Based on the CNN-BiGRU-AT Model

3.1. Model Building. In order to implement a deep learning model for predicting the emotional distribution of students' texts, a model that combines the attention mechanism and the convolutional gated recurrent unit is proposed, that is, the CNN-BiGRU-AT model. Its structure is shown in Figure 1.

The model first uses the word2vec tool to map the words in the text into a low-dimensional real number vector representation and build a matrix that represents the initial features of the text. Then, it is used as the input of the CNN-BiGRU-AT model. Finally, the backpropagation algorithm is used for end-to-end training to generate the final model. The model can classify students' text emotions based on the text represented by low-dimensional real number vectors.

3.2. CNN Text Sentiment Analysis Feature Extraction. Unlike the usual way of processing the entire text as a long sentence, the proposed model divides the text into multiple sentences. Among them, the sentence-level feature representation is extracted through the convolutional layer and downsampling layer of CNN [23].

The first layer is the input layer. The maximum sentence length L in the dataset is defined as the fixed length of the sentence. Each sentence is represented as a two-dimensional data matrix $x \in R^{d\times L}$ formed by longitudinal splicing of L d-dimensional word vectors. If the sentence length is less than L, the missing vector is randomly initialized from the uniform Gaussian distribution U (−0.25, 0.25). The two-dimensional data matrix is represented as follows:

$$x = w_1 \oplus w_2 \oplus \cdots \oplus w_n, \tag{1}$$

where $\oplus$ is the concatenation operator. $w_i \in R^d$ is the word vector corresponding to the i-th word in the sentence. The three sentences $s_i = \{w_1^{s_i}, w_2^{s_i}, \cdots, w_L^{s_i}\}$, $s_j = \{w_1^{s_j}, w_2^{s_j}, \cdots, w_L^{s_j}\}$, and $s_k = \{w_1^{s_k}, w_2^{s_k}, \cdots, w_L^{s_k}\}$ constitute the sentence input matrices x^{s_i}, x^{s_j}, and x^{s_k}, respectively.

The second layer is a sentence feature extraction layer composed of a convolutional layer and a downsampling layer. Using the CNN model structure, multiple sets of local feature maps are extracted by multiple convolution filters in the convolution layer. Subsequently, the most representative features in each feature map are extracted in the downsampling layer, and a sentence-level feature representation is obtained.

Given a sentence input matrix $x \in R^{d\times L}$, use a filter with a window size of κ to perform convolution operations on all consecutive word windows; namely,

$$y_i = f\left(\omega_c \cdot x_{i:\, i+\kappa-1} + b_c\right), \tag{2}$$

where y_i represents the i-th element in the feature map. $\omega_c \in R^{\kappa\times d}$ is the coefficient matrix. $b_c \in R$ is the bias vector. $f(\cdot)$ represents the convolution kernel function. $x_{i:\, i+\kappa-1} \in R^{\kappa\times h}$ represents a partial word window composed of κ words. When the word window gradually slides from $x_{1:\,\kappa}$ to $x_{L-\kappa+1:\, L}$, a feature map is obtained:

$$c = \left\{y_1, y_2, \cdots, y_{L+\kappa-1}\right\}. \tag{3}$$

In the downsampling layer, the max-over-time pooling method is used to sample the feature map, and the obtained feature value is

$$\widehat{c} = \max\{c\}. \tag{4}$$

A filter with a window size in the convolutional layer can extract a local n-gram feature, and C filter structures are used by changing the window size. Each filter extracts m feature maps to fully consider the contextual information between words as much as possible. The feature maps extracted by all types of filters are subjected to the maximum pooling operation of the downsampling layer to obtain a sentence feature vector F of length $C \times m$:

$$F = \left\{\widehat{c}_{1,\kappa_1}, \cdots, \widehat{c}_{m,\kappa_1}, \cdots, \widehat{c}_{1,\kappa_j}, \cdots, \widehat{c}_{l,\kappa_j}, \cdots\right\}, \tag{5}$$

where $\widehat{c}_{l,\kappa_j}$ represents the $(1 \le l \le m)$ eigenvalue produced by the j $(1 \le j \le C)$ type filter. For a text composed of L sentence sequences, the sentence feature vector $S_1, S_2, \cdots, S_L$ is obtained after the convolutional layer and the downsampling layer are sequentially pooled.

3.3. BiGRU Text Sentiment Analysis Feature Extraction. The basic unit of the gated recurrent neural network (GRNN) is the gated recurrent unit (GRU), which is a variant of the current popular long- and short-term memory network. At each time point, GRNN accepts a sentence input vector S_t and combines the output vector h_{t-1} at the previous time point to update its hidden layer node state h_t. The iteration formula is as follows:

$$\begin{cases} z_t = \sigma\left(\omega_z S_t + \lambda_z h_{t-1} + b_z\right) \\ r_t = \sigma\left(\omega_r S_t + \lambda_r h_{t-1} + b_r\right) \\ \widetilde{h}_t = \tanh\left(\omega_h S_t + r_t \otimes \left(\lambda_h h_{t-1}\right) + b_h\right) \\ h_t = \left(1 - z_t\right) \otimes h_{t-1} + z_t \otimes \widetilde{h}_t \end{cases}, \tag{6}$$

where $\otimes$ is a cross product operation. Reset threshold r_t and update threshold z_t control the information update of each hidden layer. ω_* and λ_* represent coefficient matrices. b_*

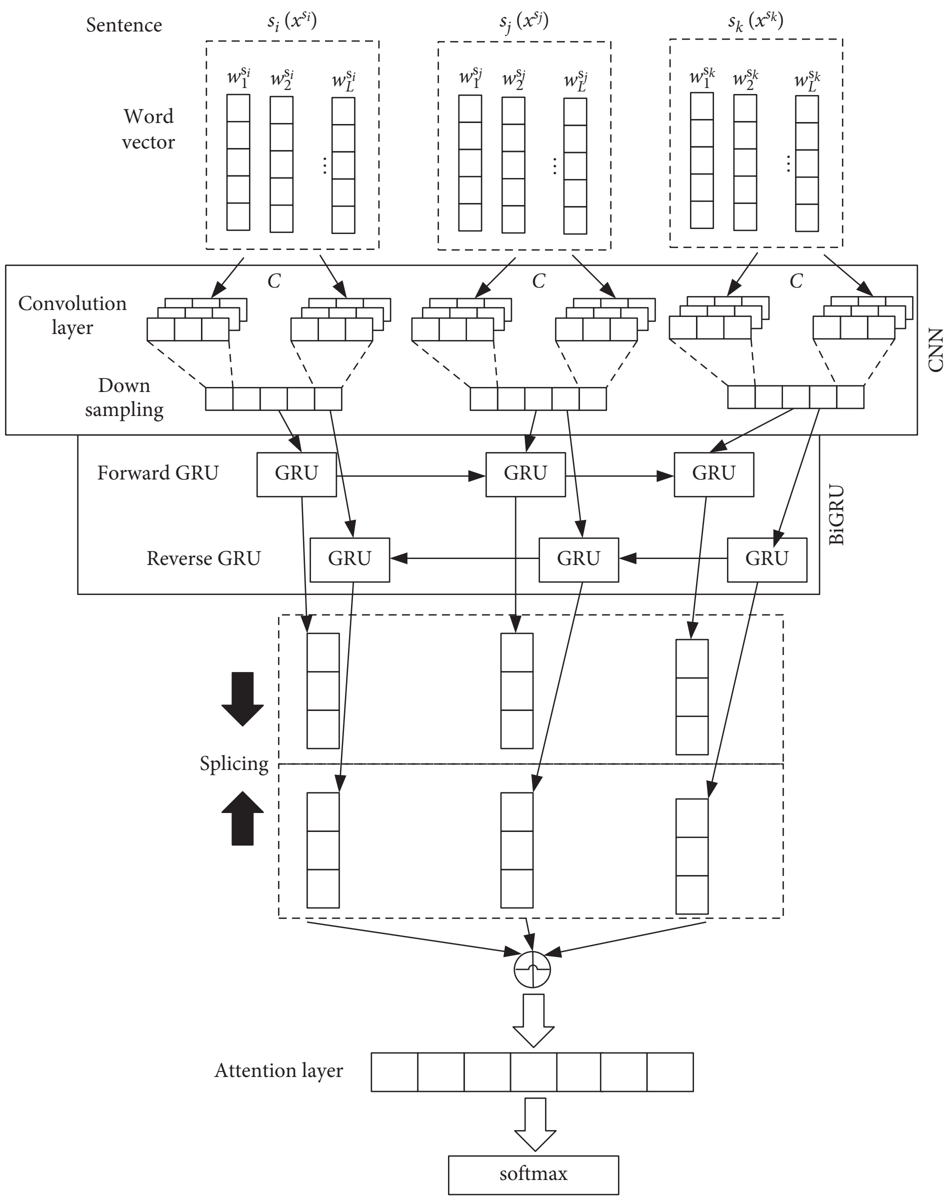

Figure 1: Structure of the CNN-BiGRU-AT model.

represents a bias vector, which is used to adaptively select and discard historical information that constructs the current semantics.

In this paper, BiGRU is used to extract the contextual semantic information features of the text. The direction of one GRU is the positive sequence direction of the input sequence, and the other is the reverse sequence direction of the input sequence. When feature extraction is performed on the input sequence, the GRUs in the two directions do not share the state. The state transition rules of GRU follow the transition occurrence between the same states. However, at the same moment, the output results of the GRUs in the two directions are spliced as the output of the entire BiGRU layer. This not only considers the above semantic information, but also considers the following semantic information.

3.4. Attention Mechanism. In the CNN-BiGRU model, CNN is responsible for extracting text features, and BiGRU is responsible for processing context and extracting sentence representations. BiGRU solves the problem of long-term dependence by adding forget gates, input gates, and output gates. The contextual semantic information processed by BiGRU is stored in a vector, but the length of the vector is fixed. When the input length of the initial sequence is extremely large, it is usually impossible to store all the semantic information in the vector. The contextual semantic information is limited, and it also prevents the model's understanding ability from reaching the ideal level [24]. Therefore, consider adding a metric that can characterize the similarity to the BiGRU model. To achieve that, the more the current input is similar to the target output, the more the weight of the current input is increased, so that the current output is more dependent on the current input. By adding adaptive weights, the model can learn more features, strengthen the generalization ability, and reduce the occurrence of overfitting [25, 26].

The essence of the attention mechanism is to calculate dynamic adaptive weights based on probability distribution. It was originally proposed by the Google Mind team and was mainly used for image classification at the time. Later, Bahdanau et al. used attention in machine translation, which also achieved good results. Nevertheless, no one has applied attention in sentiment analysis tasks. Therefore, adding the attention mechanism to the proposed model is of innovative significance. The calculation process of attention is shown in Figure 2.

The weight score is an important part of the dynamic adaptive weight in the attention mechanism, and its calculation method is as follows:

$$e_i = \chi_a^T \tanh\left(\omega_a h_i + b\right), \tag{7}$$

where h_i is the hidden layer output, ω_a is the random initialization weight matrix, χ_a is the random initialization vector, and b is the offset vector. Next, calculate the weight score ϑ as follows:

$$\vartheta = \frac{\exp\left(e_i\right)}{\sum_{k=1}^{L} \exp\left(e_i k\right)}. \tag{8}$$

According to (8), the output vector c_i weighted by the dynamic adaptive weight is

$$c_i = \sum_{j=1}^{L} \vartheta \cdot h_j. \tag{9}$$

It can be seen that the attention model connects the target matrix with the weight matrix in the neural network through a perception function. Then, use the softmax function to normalize it to get the probability distribution.

3.5. Classification Output. The classification output layer of the proposed model chooses the softmax classifier to achieve the final emotion classification. After the attention layer assigns weights to the features output by the BiGRU layer, the results are input into the softmax classifier. The classifier outputs the final result of the integration in the form of an array. Since the research object is multiemotion classification, the content in the array represents the probability of multiple emotions in the text [27, 28]. The softmax classifier calculates the probability that a sample belongs to a certain category as follows:

$$\text{softmax}\left(p_q\right) = \frac{\exp\left(w_q(x)\right)}{\sum_j \exp\left(w_j(x)\right)}, \tag{10}$$

where x represents the sample to be classified. q represents one of the j categories. p_q represents the probability that the sample x belongs to the q-th category.

At the same time, the loss function of (11) is used, and the backpropagation algorithm is used to train and update

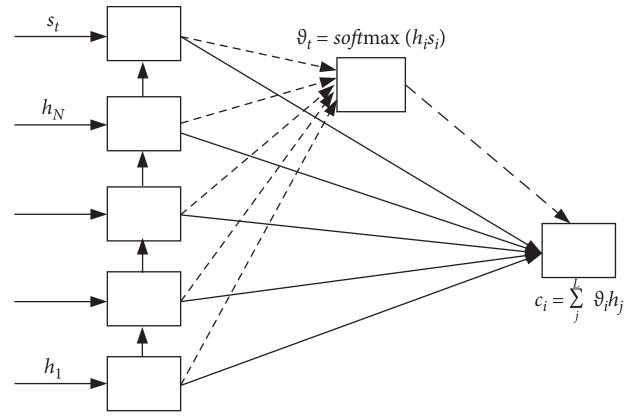

Figure 2: Calculation process of attention.

the parameter set $\theta = \{\theta_{\text{CNN}}, \theta_{\text{BiGRU}}, \theta_{\text{Other}}\}$ in the model to obtain the optimal parameters:

$$\theta = \theta - \varepsilon_1 \frac{\partial J(\theta)}{\partial J(\theta)}, \tag{11}$$

where θ_{CNN} is the parameter set of the CNN network. θ_{BiGRU} is the parameter set of the BiGRU network. θ_{others} is the parameter set of the attention layer and the softmax layer, and ε_1 is the learning rate.

4. Experiment and Analysis

In the experiment, the weibo_senti_100 k dataset (dataset address: https://github.com/SophonPlus/ChineseNlpCorpus/blob/master/datasets/weibo_senti_100k/intro.ipynb) is used to demonstrate the proposed model. The dataset contains more than 100,000 Weibo posts, all with sentiment annotations. Furthermore, the Skip-gram model in Google's open source word2vec is used in advance to perform unsupervised word vector learning on the 1.2 G Chinese Wikipedia corpus. The word vector dimension is set to 250, the learning rate is 0.01, and a distributed word vector representation model containing 520,000 words is generated. The learned word vector is stored in the vocabulary. ICTCLAS word segmentation tool is used to segment the experimental text. Used as the basic unit of sentence, the words are expressed in the form of corresponding word vectors. For unregistered words that do not appear in the vocabulary, a Gaussian distribution U (−0.25, 0.25) is used to randomly generate word vectors.

The filter window size of CNN is set to 3, 4, and 5, respectively. Each filter extracts 120 feature maps. The convolution kernel function selects the Rectified Linear Unit (ReLU) function. Both the hidden layer vector of the GRU and the context vector in the attention layer have a dimension of 120. The context vector is initialized in a randomly generated manner. During training, set the minibatch size to 64. Texts of similar length (the number of sentences in the text) are organized in a batch, and random gradient descent is performed on small batches of samples in disorder. The specific parameter settings of a single GRU are shown in Table 1.

Table 1: Parameter setting of the GRU model.

Parameter	Parameter setting
Dimension of the output of a single GRU unit	120
Iteration	100
Dropout	0.3

4.1. Classification Result Statistics. In the experiment, the number of correctly classified texts and the number of incorrectly classified texts after the classification of each emotion category in the test set are counted. The analysis results of the eight emotions are shown in Figure 3.

It can be seen from Figure 3 that the number of misclassifications of "fear," "surprised," and "happy" is relatively small, accounting for less than 10% of the total test set. Compared with other types of data, the texts of these three categories usually have explicit emotional expression words, such as "terrible," "unexpected," "shocked," and "support." Therefore, in classification, the proposed model can better capture these explicit emotional expressions. However, for emotions that lack explicit expression, such as "sadness" and "no-emotion," the proposed model has a large number of misclassifications, accounting for more than half of the total test set. Still, on the whole, the performance of the student text sentiment analysis of the proposed model is relatively ideal.

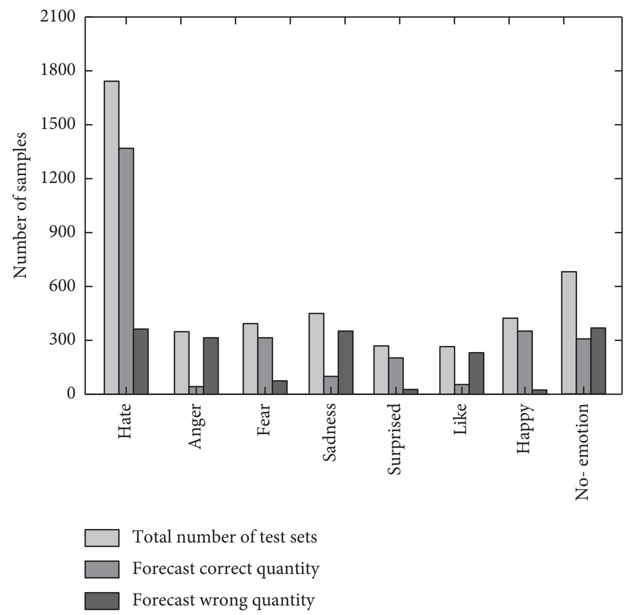

Figure 3: Text emotion classification results.

4.2. Reader Sentiment Distribution Prediction. We evaluate the ability of the proposed model to analyze students' text emotions on the experimental dataset. That is, the performance evaluation is performed by calculating the Kullback–Leibler (KL) Divergence distance between the predicted emotion distribution and the real emotion distribution. The smaller the KL distance, the better the effect of the model in analyzing sentiment distribution. The KL distance is calculated as follows:

$$KL(\widehat{p}\|p) = \sum_i \ln(\widehat{p}_i/p_i), \tag{12}$$

where $\widehat{p}$ represents the true probability value of the student's emotional label. p represents the predicted probability value of the student's emotional label.

In order to demonstrate the student text sentiment analysis ability of the proposed model, it is compared with the models in [15, 19] and [20]. The result is shown in Figure 4.

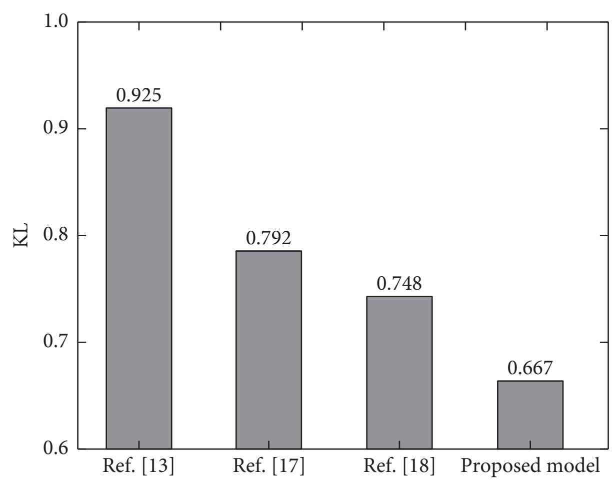

Figure 4: Comparison of experimental results of predicting students' emotional distribution.

It can be seen from Figure 4 that, compared with other models, the CNN-BiGRU-AT model can significantly improve the prediction effect, and the KL distance is only 0.667. It uses CNN to extract text features and BiGRU to process context and extract sentence representations. At the same time, using AT to link the target matrix with the weight matrix of the neural network, the model can learn more features and strengthen the generalization ability. Reference [15] uses fastText to learn emotion tags based on emotion expression dictionaries. However, with the lack of contextual considerations, the prediction effect is not good, and the KL distance is as high as 0.925. Reference [19] proposed a semisupervised learning model based on deep learning combined with long- and short-term memory to predict emotion types. The combination of models improves the accuracy of sentiment classification prediction, with a KL distance of 0.792. Nonetheless, for some emotions that are not easy to recognize, the prediction performance is poor. Similarly, [20] uses sentiment dictionary and multichannel CNN model for sentiment analysis, and the KL distance value is similar to that of [19]. However, the prediction effect of colloquial and nonstandard expression classification needs to be improved. Through comparison, it is found that the proposed CNN-BiGRU-AT model is effective in extracting the semantic features of the text with the bottom-up hierarchical structure of "word-sentence-text." Not only the semantic

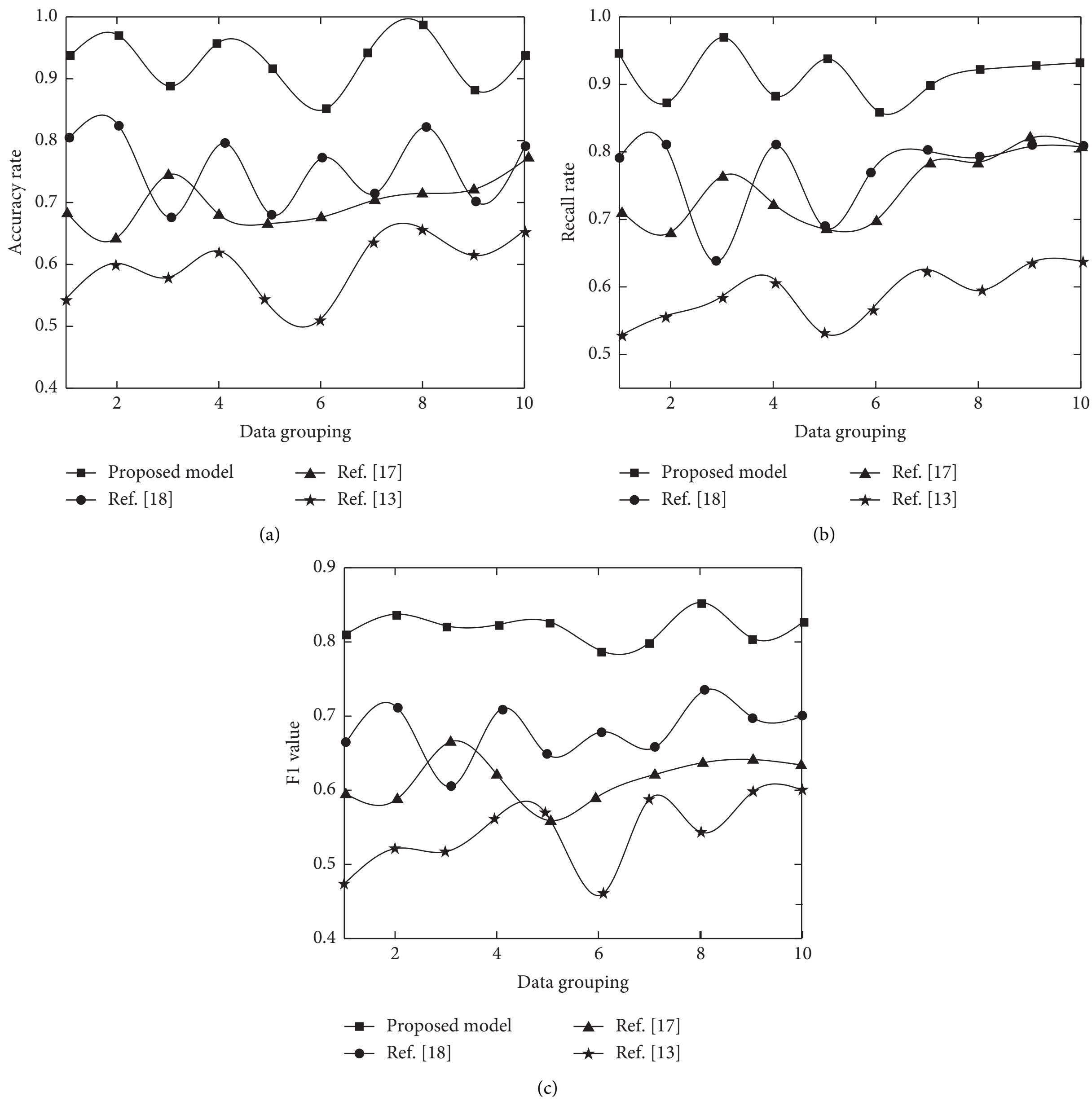

Figure 5: Performance comparison of different classification models: (a) accuracy rate; (b) recall rate; (c) $F1$ value.

information within the sentence but also the dependency relationship between the sentences is considered. In addition, the fusion of the AT mechanism can further improve the predictive ability of the model, and the obtained predictive distribution is closest to the true emotional distribution. That is, the attention mechanism can perceive contextual information and find key text features that can more affect readers' emotions, thereby improving the accuracy of emotion prediction.

4.3. Classification Performance Comparison. In order to demonstrate the effectiveness of the proposed CNN-BiGRU-AT model compared to [15, 19] and [20], a significance test experiment was designed. On the weibo_senti_100 k dataset, using word frequency as a feature, the four models are subjected to 10-fold cross-validation. The accuracy rate, recall rate, and $F1$ value of the classification results are shown in Figure 5.

It can be seen from Figure 5 that [15] uses a single fastText learning model, and the values of its three evaluation indicators are mostly distributed in the range of 0.5 to 0.6. Because the model is single and the classification of emotion types is small, the overall performance is relatively low. Reference [19] combines deep learning and long- and short-term memory network models, and [20] uses sentiment dictionary and multichannel CNN model to achieve sentiment classification, both of which use fusion models. Therefore, the performance is similar, and the values of the three indicators are mostly distributed in the range of 0.6 to 0.8. However, there is a lack of consideration of the connection between words and sentences. Therefore, the classification effect for recessive expressions is poor. The proposed model integrates CNN, BiGRU, and attention mechanism and extracts the semantic features of the text from bottom to top through "word-sentence-text." Not only the semantic information within the sentence but also the dependency relationship between the sentences is considered. Therefore, the overall performance is the best, the accuracy rate and recall rate are mostly more than 0.9, and the *F*1 value is not less than 0.8. Additionally, the results of the ten sets of data have little fluctuation, and the classification of the proposed model is more stable.

5. Conclusion

With the large-scale commercial use of 5G technology and the rapid development of the mobile Internet, social media platforms generate massive amounts of user social information every day. Obtaining people's views and emotional tendencies with high precision has become an urgent problem to be solved. To this end, a student text sentiment analysis model using the CNN-BiGRU-AT model is proposed. Among them, CNN, BiGRU, and AT are used to obtain the features of words, sentences, and texts, respectively. Through the top-down analysis of the connections between words and sentences, more features are sent to the softmax classifier to complete the classification of students' emotions. The experiment analyzes the proposed model based on the weibo_senti_100 k dataset. The results show that the KL distance is only 0.667, and the emotion prediction performance is better. In addition, the accuracy rate and recall rate of sentiment classification mostly exceed 0.9, and the *F*1 value is not less than 0.8, which are better than the results of other models. The proposed model effectively improves the accuracy of student text sentiment analysis.

At present, the CNN-BiGRU-AT model is not ideal for implicit expression analysis. However, the implicit expression analysis exists in a large number of emotional texts, so we have to face this problem in the next work. To further solve this problem, the processing of emerging network languages and nonexplicit text expressions will be strengthened to further improve students' text analysis capabilities.

Data Availability

The labeled dataset used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

Interactive Marketing E-Commerce Recommendation System Driven by Big Data Technology

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This study combs through relevant literature, adopts a combination of typical sampling and random sampling, collects three big data technology-driven interactive marketing e-commerce companies in a specific period of Sina Weibo sample data for research, obtains historical information and data, and constructs a model. Through relevant analysis to eliminate invalid variables, we creatively selected three variables of Internet hot words, activities, and microtopics as independent variables and used marketing effects as dependent variables to carry out empirical analysis and study the marketing innovation of three representative companies based on big data technology. We discussed the use of self-media in interactive marketing e-commerce and the situation of marketing innovation based on self-media, focusing on the interactive relationship between marketing innovation and Internet word-of-mouth (brand image). Through research, we have derived the three-force model, which is the biggest result of this research, and provided a reference model for interactive marketing e-commerce companies to carry out follow-up marketing innovation based on the media. Limited to the level of research and ability, there are some deficiencies in the research, such as barrage marketing, big data marketing, and emotional computing, that have not been analyzed in depth. This article fully considers the dependence of small and medium e-commerce companies on e-commerce platforms in the era of big data and conducted detailed market research on their precision marketing strategies in the era of big data. This will be a new field that does not come from media marketing. This article intends to summarize a series of experiences and laws from special to general, from individuality to generality, so as to give full play to the role of personalized marketing in increasing website traffic and order conversion, in order to personalize the use of data by other e-commerce companies with marketing provides some valuable experiences and methods for reference.

1. Introduction

With the rapid development of information technology, the arrival of big data has brought new development opportunities for scientific research, business, and technological progress. Big data has become one of the important tools in the field of e-commerce [1]. In recent years, the country's e-commerce has ushered in a period of rapid development, and the transaction volume and scale of e-commerce have expanded rapidly [2]. On the other hand, the huge user and product base of e-commerce requires e-commerce companies to build precision marketing systems based on user needs and potential needs. The rapid development of information technology and the continuous progress of network technology have promoted the vigorous development of e-commerce. The development of e-commerce is profoundly changing people's consumption and living habits [3]. The total online retail sales have accounted for one-sixth of the total retail sales of consumer goods. E-commerce has become a powerful driving force that drives national consumption and promotes national economic growth. After nearly two decades of development, the country's e-commerce market has basically matured, and a domestic retail system represented by online retail giants, such as Taobao, JD.com, and Amazon, has formed, and the industrial competition pattern has basically taken shape [4–6].

Modern society is a society with rapid development of science and technology, and the ability to process information is continuously enhanced. Information is generated by human activities and fed back to people through data analysis techniques. Big data are the product born under this background [7]. The term big data has begun to be widely used by various media. Big data analysis methods are widely used in computer, cloud computing, Internet, and and other fields [8, 9]. Scholars from all walks of life have carried out a lot of research on the methods of collecting, processing, analyzing, and using big data and achieved fruitful results [10]. Big data analysis methods take cloud computing technology as the main thrust and gradually penetrate into the analysis and research of various disciplines and industries. In addition, big data technology has been deeply integrated with enterprise management. At present, big data are not only used to promote enterprise management and market information collection but also combined with e-commerce has brought new development opportunities for all types of enterprises. The Internet and related industries have become the first source and demand side of big data [11]. E-commerce companies can use big data technology to analyze consumer needs through massive data mining, integrated analysis, and application, and they can provide consumers with personalized services and push notifications. With the continuous fermentation of big data technology, marketing strategies based on big data have also begun to be used by small- and medium-sized e-commerce companies, bringing many opportunities and challenges to e-commerce companies [12–14].

The purpose of this research is to integrate the relevant theories of the four disciplines of tourism, economics, marketing, and communication from a microperspective and examine the marketing innovation activities of interactive marketing e-commerce companies based on self-media. Therefore, the development of e-commerce big data research must be deeply integrated with relevant marketing strategies, which supported the basic strategies of precision marketing, combined with big data analysis technology, and explored the survival method of small- and medium-sized enterprises in the era of big data. Based on the gaps in academic research and the actual development needs of e-commerce companies, this article uses E-Commerce Co., Ltd. to study how e-commerce companies, especially small- and medium-sized e-commerce companies that rely on major e-commerce platforms, should adapt to the background of the era of big data. In the era of big data, we use big data technology to track changes in customer needs, better discover customer needs, cater to changes in customer needs, and carry out research on the development of enterprises. Through relevant research on the company's products, pricing, promotion, and business strategies, it discusses how small- and medium-sized e-commerce companies can do precision marketing from the perspective of the development and trend of small- and medium-sized e-commerce platforms. Through the introduction of statistical analysis, content analysis, and other techniques to establish a complete quantitative indicator system, we extract representative interactive marketing e-commerce companies, conduct comprehensive analysis and evaluation of interactive marketing e-commerce based on self-media marketing and marketing innovation, and analyze the actual situation. We stage interactive marketing e-commerce companies publish content and effects in operating Weibo accounts, sum up experience, and give suggestions for improving the marketing strategies of interactive marketing e-commerce companies.

2. Related Work

The research scope of foreign scholars is relatively wide. The first is the organization and operation of the tourism destination marketing system, marketing alliances, and their performance evaluation. The solution usually adopted abroad is to establish marketing alliances and conduct research on their development and operations. Secondly, the research also focuses on the characteristics, advantages, development issues, evaluation system, and operation of online marketing. In terms of operational research on tourism destination marketing systems, more emphasis is placed on the research on actual operational effects [15].

Malhotra and Rishi [16] referred to the tourism destination marketing system as a tourist information system. They believed that the basic theme and commonly used dominant function of DMS is to publish and process information and processing of all tourism activities-related organizations and attractions in a particular tourist area for reservation business and several core database-based application systems used in tourism information management, public information services, industry exchanges, and tourism online marketing. The e-commerce expansion model of the destination marketing system established by Hu [17] realized the three functions of commercial activities: online promotion, service provision, and transaction execution. From this perspective, the three functions of the destination marketing system are proposed with information and service provision functions, marketing functions, and transaction execution functions. Wright et al. [18] believed that the destination marketing system is an integrated marketing tool that gathers resources and services from a marketing perspective and is also a one-stop shopping center for tourists to choose and purchase products and services from the perspective of tourists. Elia et al. [19] research focused on how destination tourism information is delivered to tourists and how software and hardware equipment can meet tourists' needs. They gave particular attention to how national-level tourism agencies use this system to publicize and promote tourism destinations in the country. This concept is more appropriate to explain the functions of the national-level tourist agency information system, but its core focuses more on reflecting the function of information data processing, ignoring the other important functions of the system, namely, the interactive communication function and the needs of tourists for the function of the service. Liu et al. [20] pointed out that the destination marketing system should consider functions from two levels: management and information technology. At the management level, the system should achieve three major functions: information provision, marketing, and market research; at the technical level, three tasks must be completed: web design, website promotion, and website evaluation.

Other scholars believe that the tourism destination marketing system organically combines efficient Internet-based tourism promotion and marketing with local tourism consulting services to provide tourists with full service, which can greatly enhance the image of the tourist destination and the overall service level. The tourism destination marketing system is not only a destination information system but also a regional organization system. They pointed out that the tourism destination marketing system has competitive advantages in terms of network sales market agglomeration, the establishment of regional unified cognition, and the sharing of information resources [21]. Some scholars have introduced integrated marketing theories into the research of DMS, introduced the forms of integrating information resources, products, and services in the system, as well as introduced specific integrated methods for unified external publicity, promotion, and communication with customers. Scholars discussed it from multiple angles. Some experts also pointed out that marketing innovation is a new product, new process, or new system that has the potential to create a new market or change the existing market. They believe that marketing innovation is a general practice in a different industry, which is a jump in the rules of the game. In this way, the marketing process or the results of the marketing process are not the same as the conventional ones. Marketing innovation is a part of strategic innovation. It is a kind of corporate ability that can create value for customers, weaken competitors, and create wealth for stakeholders. The essence of innovation lies in the formation of a "communication element" and marketing activities that play its role so that users can have a sense of trust in their products and motivate them to buy. The communication element is expressed as an idea or concept, expressed as images, words, sounds, and symbols, which can give consumers a deep impression and redistribute. Researchers believe that there are two types of marketing innovation: incremental innovation and transformative innovation. Incremental marketing innovation is mainly product innovation, whereas transformative marketing innovation is technology oriented and market oriented [22, 23].

3. Construction of an Interactive Marketing E-Commerce Recommendation System Driven by Big Data Technology

3.1. Spatial Composition of Big Data Technology. Big data mean that it does not rely on sampling surveys but integrates all the data on a certain issue for analysis and processing. It is completely different from the method of sampling samples in terms of data sources and analysis methods. Big data contain the most complete reflection of the information of an event. Figure 1 shows a big data technology space architecture. Therefore, the information contained in big data is often far more than general data. The most complete information that can be reflected on the above. Compared with general data, big data contain a larger amount of information, which means more data.

The information contained in big data has gone beyond a single text form. The information of big data can be reflected in various forms, such as pictures, videos, audios, and geographic information, and it can also reflect a certain behavior from different dimensions. Therefore, the multi-dimensional nature of big data determines that an event can be reflected from more dimensions, and it also contains more useful information, but it also increases the difficulty of information processing.

$$p(x(1), x(2), \ldots, x(n)) = \prod_{i=1}^{n} p\{x(n) \mid x(n-i+1)\}. \quad (1)$$

At present, there are many ways to apply big data at the technical and decision-making levels, and there is no fixed research method. Big data analysis technology is still in the integration stage.

$$\begin{aligned} C &= 2 \times \frac{(p(x) \times p(n))^{1/2}}{(p(x) + p(n))}, \\ f(x) &= x(i) + \frac{x(i) \times x(j)}{x(i) + x(j)}. \end{aligned} \quad (2)$$

More importantly, big data are how t_o effectively collect market data, and at the same time, on the basis of further processing and researching market data, it can obtain information that is beneficial to the organization or enterprise, obtain market dynamics, understand customer needs, and adjust it. The business strategy of an enterprise, obtaining greater profits, and the scope of market operations are all important content that big data can achieve for enterprise development.

$$T^2 - \frac{1}{n} \times \sum_{i=1}^{n} (p(i) - p(x))^2 = 0. \quad (3)$$

Because big data contain a large amount of information and reflect a large number of dimensions, and the factors that play a decisive role in a certain matter often only account for a small part, so in the processing of large-capacity but low-density information, data analysis technology seems particularly important.

$$\begin{aligned} U(x) &= (I - C)^{-1} \times C^T - \sum_{i=1}^{n} p(x) \times C(i) \sum_{i=1}^{n} p(x) \times Z(i), \\ V(x) &= \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w(i,j) \times (x(i) - x) \times (x(j) - x)}{\sum_{i=1}^{n} \sum_{j=1}^{n} w(i,j) \times x(i,j)}. \end{aligned} \quad (4)$$

Big data have the characteristics of variability, authenticity, and high value. Variability refers to the fact that data are prone to change during the recording process of big data, which increases the difficulty of information processing, and

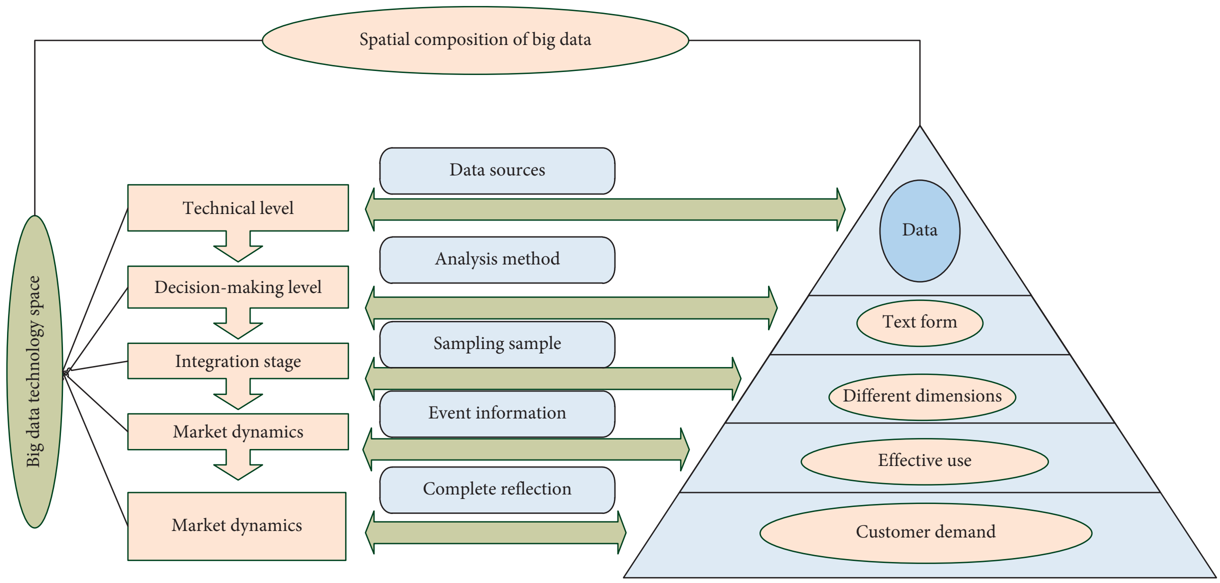

Figure 1: Big data technology space architecture.

complexity is an extension of low density. High value is the most fundamental feature of big data. Its main connotation is that if big data are used reasonably, it can derive greater value. However, the value of big data are directly proportional to the overall amount of big data collected.

3.2. Interactive Marketing Content Elements. Interactive marketing technology is a deeper method in big data analysis methods, which mainly refers to the effective analysis of data by appropriate methods from massive amounts of data. Interactive marketing technology provides technical support for precision marketing, and many scholars have made outstanding contributions in this regard. The core of interactive marketing is to analyze the characteristics of consumer behavior and to manage and research consumer groups with common characteristics based on the characteristics of consumer behavior obtained by interactive marketing. The first process of big data analysis is collection. Big data collection refers to the use of big data collection information collection platforms to collect users or other data collection tools. In the process of big data collection, the main problem is that the amount of data information is huge, the amount of data collected is high, and there are many data collection points. In the same period, a large amount of data needs to be collected at the same time. Figure 2 shows the statistical distribution of the deviation of interactive marketing data collection. Therefore, in the process of big data collection, it is necessary to establish a fairly large database, and how to further design the reasonable use and distribution of the database.

The second step is import and preprocessing, which mainly refers to the elimination of invalid information, redundant information, and low-value information after the first collection of information. Therefore, it is necessary to effectively filter and analyze the data before processing. Then, we import the obtained preliminary screening information into another large database. This step is mainly to preprocess the big data. The third step is to conduct statistics and analysis. This process is a process of further refined processing of big data. The effective data are analyzed and filtered, and statistical processing is performed, and finally, effective information is obtained. Different from the above process, big data information mining does not have a definite path or statistical analysis method. The division of labor for small- and medium-sized e-commerce companies has been further refined, and the industrialization of commodities, art, operations, inventory management, and delivery has been formally formed, which has also led to the development of models, express delivery, and other industries. It mainly uses a large amount of data collected in a database and uses various algorithms to perform calculations, which results in complex data. As far as possible to get the effect of prediction or to be able to draw other effective conclusions, the statistical analysis and mining process of big data are considered to be the key process of whether data can be transformed into value space and source of value in the process of big data information processing.

3.3. E-Commerce Platform Construction. E-commerce usually refers to the use of Internet technology, based on the browser/server application method, where buyers and sellers conduct various trade activities on the Internet platform in a face-to-face manner to realize consumers' online shopping, online payment, and various business activities and transaction activities and other new business operating models. Figure 3 shows the distribution of e-commerce platform models. The rise of e-commerce has a close relationship with the development of computer network technology, and the development history of e-commerce has a close relationship with the progress of computer network technology. E-commerce includes many models, typically, B2B (Business to Business), B2C (Business to Consumer), C2C (Consumer

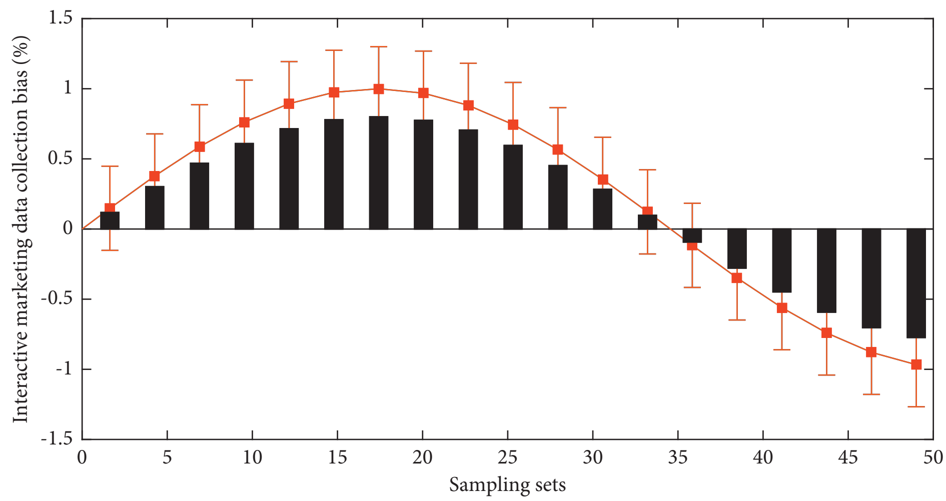

Figure 2: Statistical distribution of the deviation of interactive marketing data collection.

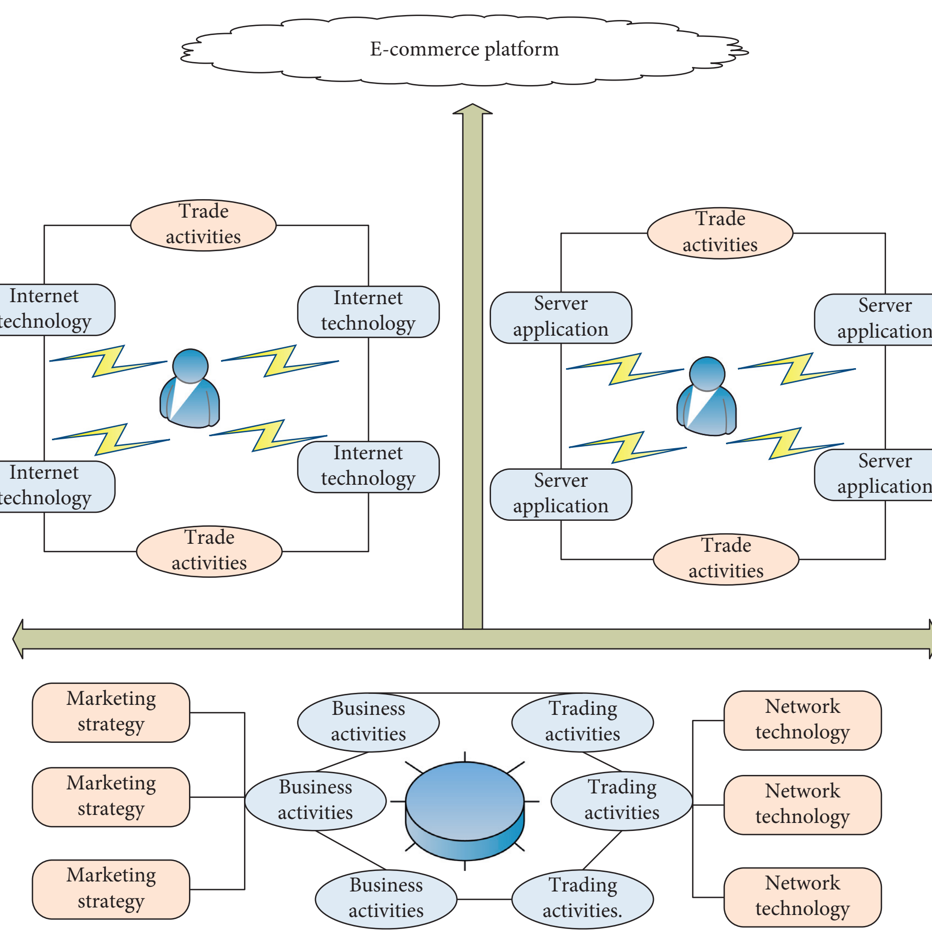

Figure 3: Distribution of e-commerce platform models.

to Consumer), and the recent emergence of P2P (Peer to Peer), and O2O (Online to Offline). Small- and medium-sized e-commerce enterprises refer to small- and medium-sized enterprises that are engaged in e-commerce business (mainly B2C, C2C, O2O) and conduct e-commerce business on large-scale e-commerce platforms. These enterprises are generally small in scale, with traffic entrances and payment methods. Goods transportation is mainly controlled by large-scale e-commerce platforms and express operators.

E-commerce platform companies provide a good development platform for small- and medium-sized e-commerce companies. Customs clearance is directly attached to large-scale e-commerce platforms, saving small- and medium-sized e-commerce companies the trouble of building their own traffic portals. Users can complete what they need on an e-commerce platform. For most of the transactions, the integrated platform operation also helps small- and medium-sized e-commerce companies develop better. However, with the increasingly fierce competition in the industry, the emergence of big data, and the transformation of small- and medium-sized e-commerce companies themselves, market competition has turned to competition characterized by the discovery and satisfaction of user needs, precision marketing strategies, and differentiated competition strategies; the combination of big data strategies is an important path for the continued development of small- and medium-sized e-commerce companies in the future. Precision marketing is a company that pays more attention to marketing actions and results when formulating marketing communication plans. This requires marketing communication and the implementation of marketing activities to be more precise, measurable, and able to achieve higher returns. Small- and medium-sized e-commerce companies have large and small data, simple and relatively complex data, and generally use Access databases or SQL-server databases. Considering that the data types and specific characteristics of user profile data may be more cumbersome, the use of NoSQL databases may be more reasonable and common. NoSQL databases are integrated with the data analysis package, which can efficiently process, organize, and manage data, which has very important advantages. The use of the database is very wide, so it is also widely used by e-commerce companies, with lower usage and maintenance costs.

3.4. System Hierarchical Weight Distribution. After having the database, the next step is to analyze the data. The analysis of the data mainly starts from the two steps of statistical data and exploratory analysis. The statistical data are mainly to analyze the existing data, from which some conclusions can be drawn, such as the popularity of the product, the consumer's preference for buying the product, the relationship between the consumer's demographic characteristics, and the purchase of a certain product or service to compare product sales with similar products or products of different categories in other stores. Table 1 shows the cluster analysis of consumer purchasing preferences. Exploratory analysis is a further level of data analysis. It is mainly to dig out some of the content and conclusions of the existing data that are not represented by the appearance, such as clustering and classification. These require unique analysis techniques, and how big the information can be extent to which the value is played also differs in this process.

The goal of precision marketing is to achieve a low-cost sales strategy through precise customer communication channel selection and sales channel selection, so that both customers and manufacturers can benefit. The core of the word "precision" in precision marketing is to focus on the needs of consumers, which means that the precision marketing system can distinguish a consumer from other consumers, and recommend the best for consumers according to their needs. It is possible that a certain product or service, instead of the previous emphasis on marketing coverage, should be broad and comprehensive. With the development of information technology, after effective integration, analysis and processing of big data generated by consumers, target consumers can be found among consumer groups, so as to achieve accurate information transmission.

Table 1: Cluster analysis of consumer purchasing preferences.

Cluster index	Popularity	Fusion rate/ %	Economic efficiency ratio
1	0.71	82.5	1.01
2	0.84	81.7	1.17
3	0.69	79.6	1.14
4	0.82	77.1	1.07

Figure 4 shows the histogram of the economic efficiency of marketing activities. We screen out the information used for identification on the website, such as baby ID; through comprehensive comparison, screen out cross-cutting and interfering data, such as "sales" in the number of sales and successful transactions; do not consider those that do not affect the decision-making factors such as store name, store reputation, and product rating. Specifically, precision marketing means that companies pay more attention to marketing actions and results when formulating marketing communication plans. This requires marketing communications and marketing activities to be implemented more accurately, measurably, and with high returns. In addition, more and more investment in direct sales. In the end, factors that have an impact on the selection of products are left: product specifications, transaction prices, and other customer-related factors; store-related factors such as the number of successful transactions and service commitments; and factors related to platform and regional sales, such as shelves. Precision marketing greatly reduces the cost of investing in unrealistic consumers by discovering potential consumers in consumer groups, improves the economic efficiency of marketing activities, and greatly reduces the cost of marketing activities themselves, but the cost reduction will not weaken the marketing activities themselves, it will increase the accuracy of the activities.

4. Application and Analysis of Interactive Marketing E-Commerce Recommendation System Driven by Big Data Technology

4.1. Big Data Feature Extraction. The dependent variable in this study is marketing effect, which can be defined as feedback from media content. This definition mainly measures the short-term effects of self-media marketing. The marketing effect index is expressed by the sum of the number of likes and the number of comments. Typical sampling is used for the selection of self-media platforms. Figure 5 shows the pie chart of the percentage of marketing effect indicators. Sina is selected as the representative from the relevant Weibo platforms, so the data come from Sina Weibo. Its

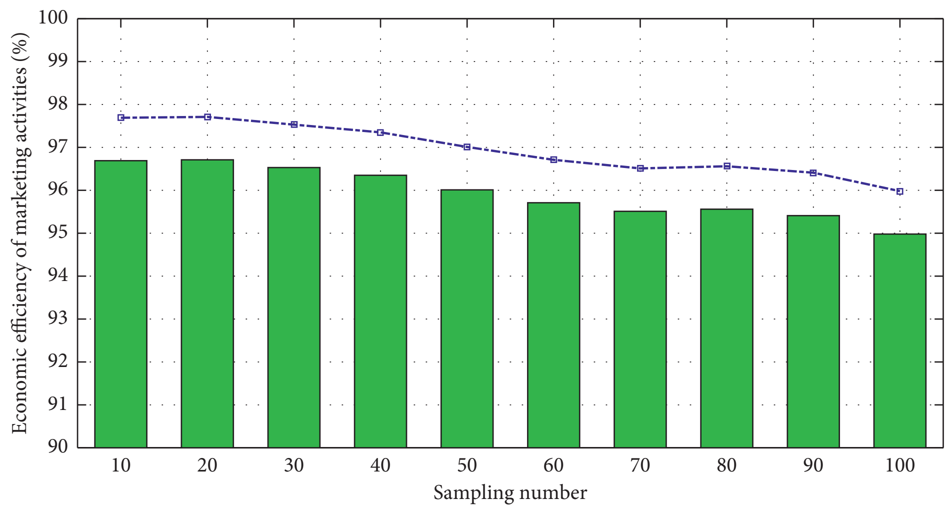

FIGURE 4: Histogram of economic efficiency of marketing activities.

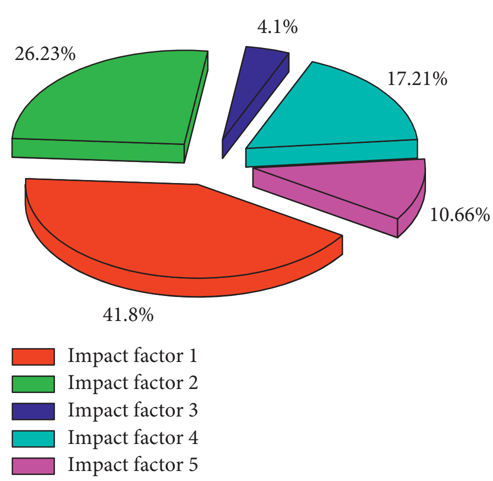

FIGURE 5: Fan chart of the proportion of marketing effect indicators.

representative significance is that Sina Weibo is the largest self-media platform, covering a large consumer group. At the same time, all major interactive marketing e-commerce companies have opened Weibo accounts on Sina Weibo, which is an important platform for interactive marketing e-commerce online marketing, which facilitates horizontal comparison between manufacturers. At the same time, Sina Weibo has the characteristics of open access, can obtain historical information and data, and can provide a sufficient number of samples. Therefore, this article chooses to collect Sina Weibo sample data from a specific period for research.

Using the network data collector, we will analyze the collected 927,174 sets of 268.88 million data. Because these data have the characteristics of large data volume, various types, and low-value density, we will do the data before analysis. After a certain amount of preprocessing, the results of this preprocessing are used to position the target market in terms of channels and regions, and in terms of product attributes and brands, to position consumer demand preferences. We take the seller's ten service promises as the product attribute influencing factors that influence customers to choose between different brands, set it as a dummy variable to introduce the model, and use the MNL model to predict the probability of customers choosing between different brands, which is then the company's selection of promotion channels during the product launch process that provides a basis for decision-making. From the perspective of consumer preferences, we analyze different platform structures through data, and make a certain analysis of which category and which brand of products sell well and the positioning of average prices. Specific to the price range, we discover the potential purchasing power and consumption range of the target customer group; through the analysis of product attributes, we can find out which features of the product will be particularly favored by consumers. Finally, it provides a basis for company A's precise marketing decision on the product.

4.2. E-Commerce System Evaluation. Because the total number of microblogs in the three sample companies exceeded 2,000 within a year, the existing research methods are not sufficient to analyze all of them. Therefore, this article adopts the method of random sampling by computer. We establish a personnel service feedback and evaluation system and establish a personnel efficiency database based on big data. Based on consumer feedback to various service personnel, company internal evaluation system information, and basic information data, the performance of employees can be analyzed and compared, various personnel arrangements can be made, and avoidable accidents can be predicted. The specific steps are to use the random sampling function of the *R* language, and each manufacturer will sample three months. Secondly, we extract the page numbers of each manufacturer in each month. According to power analysis, this number of microblogs can represent the total sample during the study at a significance level of 0.95. After we have a detailed understanding of the requirements, we need to sort out the data collected on this page. In the end, I chose the store name, product name, price, and number of successful transactions as the collection object. Figure 6

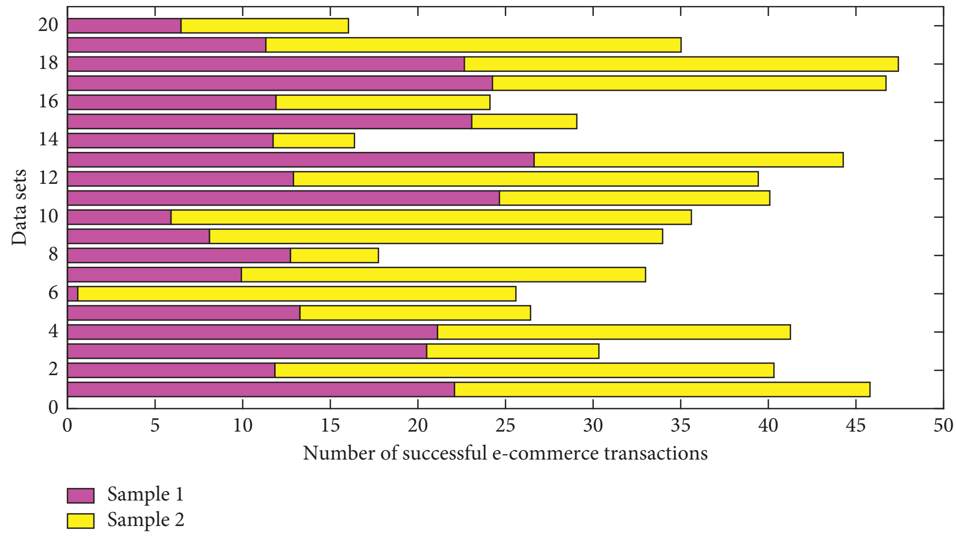

Figure 6: Histogram of the number of successful e-commerce transactions.

shows the histogram of the number of successful e-commerce transactions. After completing the data collection, the second step is to classify and filter the data: which are the information used by the website for identification and do not have the value of data exploration and mining; which data are almost duplicated and can be eliminated in half; and which data need to simultaneously consider and get useful data.

The information included in the transaction data that I finally sorted out includes product type, platform, store name, store reputation, product rating, store location, title, baby ID, brand, product specifications, whether it is free shipping, title, price, transaction price, sales volume, number of successful transactions, number of comments, number of favorites, and payment methods. After screening, there are 174 groups of valid and complete data information. Although the target of collaborative filtering technology is specific users, it cleverly uses the information of all users. Recommendations are mainly based on the preferences of other users who are most similar to the user. There are many ways to calculate similarity, such as cosine similarity (the denominator is the square root of the product of the number of products purchased by two users). After we calculate the similarity, we can sort the preferences of other users on the products according to the similarity weighted summation method and then recommend them to specific target users. This collaborative filtering recommendation technology can not only accurately infer the potential needs of users, but more importantly, it can increase cross-sales, that is, when users purchase a certain category of products, they recommend other categories of products to users, thereby increasing the diversity of high user purchases.

4.3. Example Application and Analysis. Content-based recommendation technology is one of the important contents of personalized marketing in the era of big data. This technology originated from information retrieval and information filtering, and its root lies in the acquisition and quantitative analysis of content. Because the research in text information acquisition and filtering is relatively mature, most of the current content-based recommendation systems are mostly the text of the product information operation after analyzing. Coding is to place the analysis unit in the category system. For the first time, we have arranged a week to train coders and improve the coding plan based on the training situation to make the understanding between coders similar to achieve the predetermined reliability. Second, we conduct preresearch to check the reliability of coders and ensure that they master coding skills and methods. Third, in the formal study, standardized tables are used, and computer-aided coding and statistical work are used. Based on similar research, we use a category system to classify each Weibo. The classification is carried out from the three levels of Weibo's basic information, content category, and form, and 21 subcategories are determined to try to exhaust the possibilities of interactive marketing e-commerce microblogs and produce meaningful results.

Figure 7 shows a stick chart of the significance test of e-commerce product categories. To analyze the data of the target product, it is first necessary to separate the data that meet the requirements from the 100 sets of data that have been preliminarily sorted out. After preliminary screening, 100 sets of target product data were obtained, and then, service commitment attributes were selected among them as the data basis for modeling. Next, we need to analyze and process this part of the data. We will use 70% (the first 50 groups) of samples as training samples for modeling and analysis. In addition to taking security measures to protect consumers' personal information, the industry has also developed a star-rated label on the web page to allow consumers to identify the company's logo for safeguarding consumer data. We will substitute variables into the MNL model and use SAS to test them for empirical analysis, and based on the results of this analysis, we make the choice of promotion channels for the products on the shelves. After

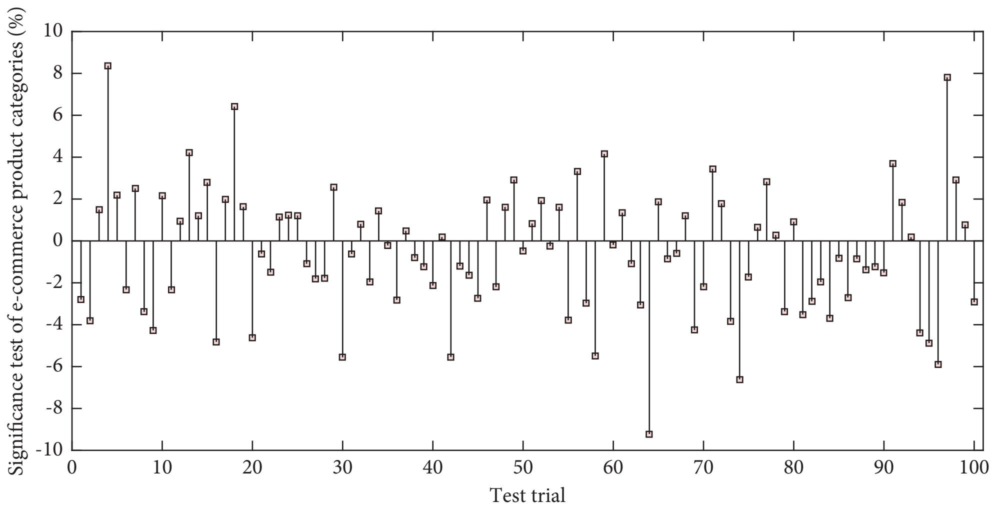

FIGURE 7: Matchsticks for the significance test of e-commerce product categories.

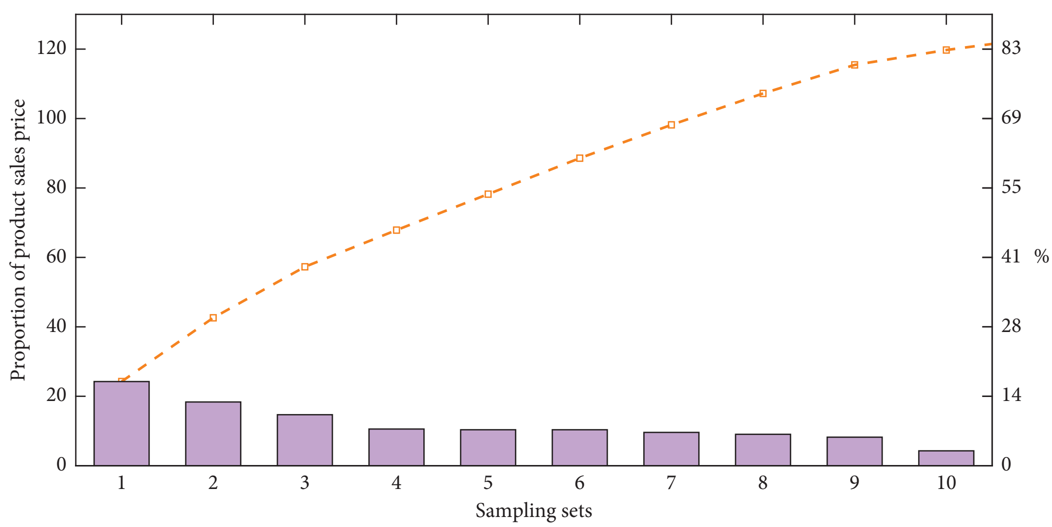

FIGURE 8: Line chart of product sales price percentage.

the model is obtained, the model is used to predict the remaining 30% (15 groups) of the test samples, and finally, the prediction results are tested. Using 70% (the first 50 groups) of samples as training samples, the following results are obtained through repeated screening of variables. Obtaining the data summary, the significance test of the respective variables' influence on the overall model, and the estimated value and significance test of the respective variables are given. It can be seen that the variables VAR18, VAR19, and VAR25 all passed the significance test. The last line is the likelihood ratio test of the goodness of fit of the model. The likelihood ratio statistic is 6.93, and the statistical result is not significant ($p = 0.0743$), which shows that the fitted model is acceptable. The last column gives the results of the significance test of each independent variable for each MNL model, in which the coefficient estimates of the remaining independent variables are not significant except for the estimated value of the second coefficient of VAR18 and the estimated value of the third coefficient of VAR19. All passed the significance test.

Figure 8 shows a line chart of the percentage of product sales prices. It can be seen that in terms of product prices, from the perspective of Taobao's entire network, the product industry's most shipped price range is between 11 yuan and 22 yuan, of which shipments accounted for 27.9%, and the high sales price range is between 22 yuan and 33 yuan, of which sales accounted for 14.3%. In addition, there is a significant increase in the range of 333–432 yuan, indicating that most consumers still choose relatively low-end cosmetics and do not pursue branded products; the other part tends to buy branded products, focusing on products purchased in several well-known brands, although the products at the midprice range are seldom bought. Judging from the basic information of the research subjects, they have the ability to read and understand the questionnaire of this research and can accurately express their opinions.

Therefore, the data of this questionnaire are valid. The sales of normal specifications accounted for the highest proportion, accounting for nearly 90% of the market share, whereas the choice of suits was less, indicating that consumers' demand is only to choose a certain type or a certain fragrance of the product according to their preferences, rather than buying a certain brand. For a full set of products, some consumers tend to prefer to purchase the corresponding light-backed products, and such consumers may prefer to use them for their own use.

5. Conclusion

This article mainly studies the precision marketing system based on big data, sorts out the history of e-commerce development, discusses the possibility of combining big data and precision marketing systems, and analyzes the major e-commerce platforms and enterprise application of big data technology in the era of big data. At the same time, the study is carried out with it as a typical case, focusing on small and medium e-commerce companies, especially small e-commerce companies that rely on e-commerce platforms, such as Amazon, JD.com, and Taobao, to carry out the real possibility and necessity of precision marketing based on big data. Based on practical factors, this article designs a general system platform based on general big data precision marketing strategies and uses clustering algorithms as an example to illustrate the use of the system. At the same time, from the aspects of improving enterprises' understanding of big data strategy and precision marketing, applying big data to adjust corporate marketing strategies, precision marketing channels, deepening consumer demand analysis, applying big data analysis results to optimize business operations, and the like, it proposes to optimize the precision marketing of system countermeasures and suggestions. In most cases, the measurement of validity is the measurement of construction validity, and the measurement of construction validity is carried out through confirmatory factor analysis. Specifically, it is judged by the standardized factor loading of the item, if the fit is good, then it can be further tested for validity through standardized factor loading coefficients. This study avoids the complicated model construction and high-specialization design and selects the MNL model (Multinominal Logit Model), which is simple in model construction and widely used in data analysis, to quantitatively construct the predictive model and obtain the customer's purchase probability, and it achieved a high accuracy rate, rather than a general qualitative analysis, so that small and micro e-commerce merchants can more targeted product selection and sales, which can provide a basis for e-commerce precision marketing but also have a high actual operation. We hope that through the analysis of typical cases in this article, we can develop precision marketing strategies for small- and medium-sized e-commerce companies in the future and provide a good reference and experience.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors do not have any possible conflicts of interest.

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Research Article

A Mobile Bayesian Network Structure Learning Method Using Genetic Incremental K2 Algorithm and Random Attribute Order Technology

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The application of existing datasets to construct a probabilistic network has always been the primary research focus for mobile Bayesian networks, particularly when the dataset size is large. In this study, we improve the K2 algorithm. First, we relax the K2 algorithm requirements for node order and generate the node order randomly to obtain the best result in multiple random node order. Second, a genetic incremental K2 learning method is used to learn the Bayesian network structure. The training dataset is divided into two groups, and the standard K2 algorithm is used to find the optimal value for the first set of training data; simultaneously, three similar suboptimal values are recorded. To avoid falling into the local optimum, these four optimal values are mutated into a new genetic optimal value. When the second set of training data is used, only the best Bayesian network structure within the five abovementioned optimal values is identified. The experimental results indicate that the genetic incremental K2 algorithm based on random attribute order achieves higher computational efficiency and accuracy than the standard algorithm. The new algorithm is especially suitable for building Bayesian network structures in cases where the dataset and number of nodes are large.

1. Introduction

The effective expression of uncertain knowledge is an important content of knowledge intelligent learning. In this research field, Bayesian network has always been the focus of attention. Bayesian network is a probability graph model. It represents the dependency relationship between a group of random variables through a directed acyclic graph. The conditional probability table (CPT) formed by each variable represents the probability relationship between variables [1]. It has strong uncertainty reasoning ability, which can realize top-down prediction analysis and bottom-up diagnostic inference [2]. Machine learning technologies have become more and more important in many applications, such as medicine [3], e-commerce [4, 5], transportation [6], and image denoising [7]. As one of the machine learning technologies, Bayesian network is widely used in many fields, such as machine vision, biomedicine, classification, fault diagnosis, prediction, natural language processing, and data mining [8].

The Bayesian network is primarily based on Bayesian network learning, which is divided into two steps: structural learning and parameter learning. Structure learning is to obtain a directed acyclic graph that can represent attribute dependencies based on training data and a priori knowledge. Parameter learning is to obtain the conditional probability of each node based on the directed acyclic graph. It is usually called conditional probability table. In these two learning, structural learning is more difficult, and it is also a research hotspot. It mainly focuses on how to avoid falling into local optimization and find the best structure when there are many attributes and few sample data [9, 10].The Bayesian network structure learning algorithm can be divided into a method based on scoring and searching, the conditional independence test, and a hybrid of the two methods.

(1) Method based on scoring and searching: it uses the scoring function to measure the matching degree between the Bayesian network structure and the training sample set. After defining the scoring function, apply the search strategy to find the network structure with the highest score. K2 algorithm is the common one [11]. Due to the constraint of node order, K2 algorithm can effectively avoid the problem of likelihood equivalence and is better than most classical algorithms in running speed and accuracy. However, in most cases, the node order is unknown and usually needs to be determined according to expert knowledge. The difference of expert knowledge is large, which cannot ensure objectivity and accuracy, and it is difficult to achieve when there are a large number of nodes. Therefore, researchers have put forward many solutions. It is proposed that conditional frequency is used to determine the node ranking of K2 algorithm. The algorithm does not need complex search strategy and effectively reduces the time complexity. However, it has high requirements for the quality of data set and is not easy to obtain the accurate model [10]. Combining the maximum spanning tree and ant colony algorithm, the MUST-ACO-K2 (MAK) algorithm is proposed to search the node order, but the algorithm needs to substitute the obtained node order into K2 algorithm to get the network structure before scoring, resulting that its running time is too long [10].

(2) Method based on conditional independence test: this method abstracts the learning process of the Bayesian network structure as the process of discovering a set of variables hidden in the network structure that satisfy the independence condition test. Spirtes proposed the SGS algorithm in 1989 [12], which uses conditional independence to test the existence and direction of edges and eliminates the prior constraint of the K2 algorithm that requires a given order of nodes, but the cost of the test calculation is exponential. In the second year, he proposed a PC algorithm [13], which improved upon the search strategy of the SGS algorithm. It requires less computational load when learning a sparse network structure, and it was used by Tsagris [14]. Cheng combined the idea of information theory with an independent testing method [15], and the proposed learning method exhibited good performance in structural learning.

(3) Hybrid algorithm: because the method based on score search and the method based on constraint have their own advantages and disadvantages, the hybrid optimization algorithm combining the two has gradually become the mainstream of research. The improved whale optimization algorithm is used to optimize the structure of Bayesian network. The optimization efficiency and accuracy of this method are good, but the complexity is very high [16]. The improved particle swarm optimization (PSO) is proposed to learn the Bayesian network structure. After the initial network is constrained by mutual information, the improved PSO algorithm is used to search the optimal Bayesian network, which improves the optimization efficiency. However, due to the instability of the algorithm, the accuracy of the structure cannot be guaranteed [17]. The bird swarm algorithm is used as the search strategy to improve the search strategy, which makes the search ability stronger and the convergence further improved [18].

For the K2 algorithm, as stated by Cooper, the K2 algorithm can reconstruct a moderately complex belief network rapidly, but it is sensitive to the ordering of the nodes [11]. Further information can be found in [19, 20].

This paper presents a new Bayesian network structure learning method based on random node order and genetic incremental search for an optimal path and compares this method with the K2 algorithm. Experiments demonstrate that the method of random node order can yield a better Bayesian network structure without expert knowledge, and the genetic incremental structure learning method can greatly improve the computational efficiency when tested on big datasets, especially when the number of samples and nodes are large. It always exhibits a runtime that is shorter than that of the K2 algorithm.

2. K2 Algorithm

The K2 algorithm [21] effectively integrates prior information in the search process and exhibits good time performance. It is a classic structure learning algorithm based on scoring search.

2.1. Scoring Function. The node sequence is given in advance, and each node greedily searches its parent node set from its predecessor node according to the Bayesian scoring function and finally obtains the network structure with the best score.

The learning of the network structure can be attributed to the given dataset D and finds a network structure B_s with the largest a posteriori probability, that is, B_s is set to maximise $P(B_s|D)$. Additionally, $P(B_s|D) = P(B_s|D)/P(D)$, the denominator $P(D)$is unrelated to B_s, so the ultimate objective is to find the maximum B_s of $P(B_s|D)$. Through a series of derivations (for the specific derivation process, see [6]), we obtain

$$P(B_s|D) = P(B_s)\prod_{i=1}^{n}\prod_{j=1}^{q_i}\frac{(r_i-1)!}{\left(N_{ij}+r_i-1\right)!}\prod_{k=1}^{r_i}N_{ijk}!, \qquad (1)$$

where $P(B_s)$is the priori probability of B_s. This is the probability set for each structure without providing data. N_{ijk} denotes the jth unique instantiation of π_i relative to D.

Suppose there are q_i such unique instantiations of π_i. Define N_{ijk} to be the number of cases in D in which variable x_i has the value v_{ik} and π_i is instantiated as w_{ij}; the value of N_{ij} can be obtained using

$$N_{ij} = \sum_{k=1}^{r_i} N_{ijk}. \tag{2}$$

For equation (1), the first multiplicative symbol traverses each random variable x_i by i, and n denotes the number of random variables.

The second multiplicative symbol traverses all parent variables of x_i by j, and q_i indicates the number of types of x_i parent variable instances.

The last multiplicative symbol traverses all possible values of the current variable x_i, where r_i denotes the number of possible values.

It can be assumed that the probability of each structure obeys a uniform distribution, that is, the probability $P(B_s)$ is the same constant as c. Using constant c to replace $P(B_s)$, equation (1) changes to

$$P(B_s|D) = c\prod_{i=1}^{n}\prod_{j=1}^{q_i}\frac{(r_i-1)!}{\left(N_{ij}+r_i-1\right)!}\prod_{k=1}^{r_i}N_{ijk}!. \tag{3}$$

The objective is to obtain B_s that can maximise the posterior probability, as follows:

$$\max_{B_s}\left[P(B_s, D)\right] = c\prod_{i=1}^{n}\max_{\pi_i}\left[\prod_{j=1}^{q_i}\frac{(r_i-1)!}{\left(N_{ij}+r_i-1\right)!}\prod_{k=1}^{r_i}N_{ijk}!\right]. \tag{4}$$

As can be seen from the above equation, as long as the local maximum for each variable is provided, the overall maximum can be obtained. The component of each variable is presented as a new scoring function, as follows:

$$g(i, \pi_i) = \prod_{j=1}^{q_i}\frac{(r_i-1)!}{\left(N_{ij}+r_i-1\right)!}\prod_{k=1}^{r_i}N_{ijk}!. \tag{5}$$

2.2. Search Strategy. The core of Bayesian network structure optimization is to narrow the search scope through search strategy after determining the scoring function. Greedy search algorithm is the most commonly used method. But it is easy to fall into local optimization. In 2017, the authors of [1] proposed adding disturbance factor to local greedy search, and using the idea of genetic algorithm, the metaheuristic method was used to improve the performance of local greedy search. In 2020, the authors of [22] introduced microbial genetic algorithm into Bayesian network structure learning. The undirected graph with most correct edges is calculated by the maximum information coefficient, and it is used as the initial population, and then the excellent individuals in the initial population are retained by using the operator of microbial genetic algorithm. Through the combination of the two, the purpose of learning close to the real network structure from a small amount of data can be achieved. Search strategy assumes the nodes are ordered. If x_i precedes x_j, there can be no edges from x_j to x_i. Simultaneously, it assumes that the maximum number of parent variables per variable is u. Each time the largest parent variable of the scoring function is selected and inserted into the set, the loop is terminated, and the scoring function cannot be increased further.

3. Incremental K2 Algorithm Based on Random Attribute Order

3.1. Random Generate Nodes Order. The K2 algorithm must initialise the order of nodes such that only the node in front of node i can be the parent of node i. This is defined as

$$\mathrm{Pred}(x_i) = x_j\,(j = 1, 2, \ldots, i-1). \tag{6}$$

The disadvantages are as follows. First, the order of nodes is not easy to obtain in most actual network structures, and the expression of this a priori knowledge is not conducive to the understanding of expert knowledge. Second, the fault tolerance for the order of nodes is poor. If the order of nodes that is input into the K2 algorithm is dissimilar to that in the real structure, the accuracy of the K2 algorithm will be greatly reduced; this is owing to its algorithmic theory. In this study, our first objective is to reduce the dependence on the order of nodes. For nodes, each iteration randomly generates an array of nodes, and the generation procedure (see Algorithm 1) is as follows.

3.2. Genetic Incremental K2 Algorithm. The basic idea is to divide the training data into two groups and use the first set of training data to learn a basic Bayesian network structure using the K2 algorithm. In the process of learning, not only the current optimal value, i.e., the decision-making of the algorithm each time, but also several suboptimal values are saved [23], a GA is applied, and the current four optimal values are mutated to a new optimal value. The number of suboptimal values can be adjusted, for example, three or four. This study selects three suboptimal values. When using the second set of incremental data, it will not research; instead, it will take the four optimal values and the new genetic value as the next search space. The algorithm skilfully eliminates the low-level model, reduces the search space, and improves the efficiency of the algorithm.

In addition, the optimal score function value is preserved in each iteration. After the iteration, the node order of the Bayesian network with the optimal score function value is considered to be the best node order.

The algorithm is divided into two parts. The first part (see Algorithm 2)is to generate one optimal value and three suboptimal values, mutate a new optimal value from the first set of data, and store all values in the candidate matrix. The following pseudocode expresses the first part.

The second part (see Algorithm 3) of the algorithm uses the second set of data to optimize the suboptimal value. The core content is as follows.

```
Procedure randomarray(len, start, end) (
  {Input n, n is nodes number.}
  {Output: an array that has n values between 1 and n.}
    Define the array[1,n]: order
      for1 1-n {
        Random generation of a number between 1 and n
        If (the number is the first number) {insert the number into the array; }
          Else{
          for2 1-length(array){
        If(the number exits){ regenerate a random number, loop for2}
      else{insert the number into the array; loop for1}
      End for2}
    End else }
  End for1}
End randomarray }
```

Algorithm 1: Random array algorithm.

```
Procedure GCDK2{
{Input: K2 algorithm need parameter initialisation, mutation rate pm = 0.5}
{Output: a bayesian network and a matrix contain optimal value and location }
  For i = 1-n{
  P_old = g(i, π_i)
  While OK To Proceed and Length is OK
    pps = mysetdiff (order (1: i − 1), ps){Potential parents}
    nps = length (pps)
      For pi = 1-nps{
    pscore (pi) = g(i, π_i ∪ {z})
  End for}
[P_first, best_p_first] = max (pscore);{best_p_first is a location, P_first is the max first score}
    Get second_pscore and second_p
Get third_pscore and third_p
      Get fourth_pscore and fourth_p
      Mutate optimal values get a new genetic value GA_pscore
      If (P_first > P_old) {P_old = P_first;ps = [ ps  best_p_first ]
      Input P_first best_p_first second_pscoresecond_p,third_pscore ,
    third_pfourth_pscore,fourth_p and GA_pscoreinto candidate matrix
    End if}
  End while}
End for}
End GCDK2}
```

Algorithm 2: GCDK2 algorithm.

4. Experimental Results

To test the algorithm, the general ALARM, Asia, and CANCER networks were selected in the experiment. Under different sample numbers, the running time and structural hamming distance [24] were used to evaluate different algorithms.

The experiment adopted the Bayesian network toolbox in the MATLAB platform. The operating environment was Windows 7, Intel (*R*) Core(TM) i3-4170, 3.70 GHz CPU, 8.00 GB RAM. The results of the experiment are listed in Tables 1 and 2.

This algorithm relaxes the strict requirement of the K2 algorithm on node order and improves the efficiency of learning the Bayesian network structure.

(1) In the ALARM network (comprising 37 nodes), the experiment began with a sample size of 4000, the running time of K2 was 7.928, GAK2 was 5.675, and GIMK2 was 0.861; when the size varied to 50000, the times were 29.877, 18.429, and 3.128; when the size was 100000, the times were 55.659, 37.839, and 5.987. SHD is large at first; however, it eventually reduces to zero.

```
Procedure GIMK2(part){
  For i = 1-length (candidate)
  child = candidate (i, 1)
  For j = k to k+4 {from k to k+4 because the candidate stored 5 values}
    ppar = candidae (i, j)
    u = find (clamped (child, : ) == 0)
    Get P_new from child and u
  End for
  best_action = candidate (i, best_p)
  End for
  . . .
End GIMK2}
```

Algorithm 3: GIMK2 algorithm.

Table 1: Result of learning ALARM by learn_struct_K2 and GIK2.

Sample size	K2		GAK2		GIK2	
	Time (s)	SHD	Time (s)	SHD	Time (s)	SHD
4000	7.928	2	5.675	2	0.861	2
5000	8.348	2	6.253	2	0.831	2
10000	11.047	2	8.754	2	1.110	2
15000	12.740	2	10.546	2	1.348	2
20000	15.456	1	11.328	1	1.547	1
50000	29.877	1	18.429	1	3.128	0
100000	55.659	0	37.839	0	5.987	0

Table 2: Result of learning Asia by learn_struct_K2 and GIMK2.

Sample size	K2		GAK2		GIK2	
	Time (s)	SHD	Time (s)	SHD	Time (s)	SHD
200	0.234	3	0.205	2	0.058	2
500	0.240	1	0.218	1	0.073	1
1000	0.255	1	0.220	1	0.057	1
3000	0.225	1	0.231	1	0.062	1
5000	0.232	1	0.236	1	0.078	1
10000	0.264	1	0.238	1	0.089	1
15000	0.291	0	0.247	0	0.141	0
20000	0.376	0	0.275	0	0.137	0
50000	0.593	0	0.279	0	0.235	0
100000	1.084	0	0.884	0	0.423	0

(2) In the Asia network (comprising 8 nodes), the experiment began with a sample size of 200; however, when the size varied to 5000, the running time of K2 was 0.232, GAK2 was 0.236, and GIMK2 was 0.078; when the size varied to 50000, the times were 0.593, 0.279, and 0.235; when the size was 100000, the times were 1.084, 0.884, and 0.423.

(3) In the CANCER network (comprising 5 nodes), the experiment began with a sample size of 200; however, when the size was 5000, the running time of K2 was 0.158, GAK2 was 0.139 and GIMK2 was 0.053; when the size varied to 50000, the times were 0.248, 0.218, and 0.188; when the size was 100000, the times were 0.353, 0.245, and 0.191.

The results of the program operation indicate that the genetic incremental K2 algorithm has a shorter running time than K2 and GAK2 for the same sample size. When the mobile Bayesian networks with different number of nodes, particularly when the dataset size increases with the number of nodes, the running time of K2 and GAK2 becomes extremely long.

5. Conclusion

As data analysis is now being conducted on big data, if we need to analyse big data with uncertain knowledge, especially in the case of numerous attributes, the genetic incremental K2 algorithm can reduce the search space and considerably improve the efficiency of the algorithm. The improved algorithm in this paper is effective; however, it has disadvantages such as the fact that the search space of each algorithm depends on the current optimal path; thus, it is easy to fall into local optimum. The algorithm should thus combine particle swarm optimization, ant colony, or another optimization algorithm to avoid falling into local optimum.

Data Availability

The labeled dataset used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

A Novel Trade Transaction Agreement Algorithm Using Blockchain Consensus Mechanism

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Blockchain, the underlying technology of Bitcoin, has been deeply studied in various fields after its development in recent years. As a typical decentralized distributed data storage system, consensus reached among all participants in a blockchain system requires a consensus mechanism to be realized. In order to make blockchain applicable to different application scenarios, different consensus mechanisms have been proposed. With the further development of blockchain applications, more and more studies have been conducted on the consensus mechanism. However, some existing consensus mechanisms still have some problems in various aspects. Therefore, this paper proposes a trade deal algorithm based on the blockchain mechanism of consensus. First of all, according to PBFT, the lack of a dynamic problem in the VPBFT voting mechanism was introduced. The node system is divided into four types with different responsibilities and gives the number of relations between nodes. When the number of nodes is changed, it can be calculated according to the quantity relation, ensuring dynamic. Second, a data anonymous transaction and authentication protocol is designed. In the protocol, when the seller sells data, the mapping relationship between the real identity and the false identity of the data owner is blinded and sent to the buyer. When the buyer wants to verify their identity, the seller's identity can only be verified with the authentication of the blockchain. The proposed algorithm is superior to the current consensus in terms of time and energy consumption, throughput, and fault tolerance methods, which is proven through experimental tests and simulation analysis.

1. Introduction

Blockchain [1] is a decentralized distributed database characterized by decentralization [2], immutability [3], anonymity [4], autonomy [5], consensus, and other characteristics. It is a new technology that has the potential to change social interaction and trading methods. This technology's main benefit is its ability to exchange transactions without relying on trusted third-party entities in any way. Data integrity, built-in authenticity, and user transparency are all features it can provide. Blockchain is a decentralized distributed computing paradigm, not a technological innovation. The data structure it adopts is a series of data blocks formed in a chain in time sequence. It involves various technologies of cryptography and integrates technologies such as smart contracts [6], P2P networks [7], and consensus mechanisms. Cryptography is used to ensure that data blocks in the chain of ownership and right of privacy, due to the data block in the chain is electronic data. It is not easy to prove to belong to source and transparent data. As a result, we will need to include some information in the data signature to indicate the data and sources as well as some cryptography technology to ensure privacy and prevent data leaking. Smart contracts, which are programs or scripts that can be automatically triggered and executed, ensure that bookkeeping participants conduct transactions and bookkeeping in accordance with certain rules [8]. They use algorithmic scripts to implement some commercial logic rules and regulations, ensuring that blockchain can be used in more systems. To ensure the consistency of the generated data across the entire distributed system, a consensus mechanism is used. Because blockchain is a distributed and open network, there is no or little trust between the transaction's two parties. In order to reach a consensus on a specific topic, the consensus mechanism is critical.

Consensus [9] has always been a hot topic in the field of distributed systems research. As people's cognition has deepened and blockchain research has advanced, relevant research on the consensus mechanism to solve the consensus problem has become a hot research topic in recent years. In a distributed system, the so-called consensus problem occurs when all participants have the same status. The distributed system is maintained, checked, and maintained by each participant in the same way. As a result, a consensus mechanism ensures that all participants in a distributed system can trust one another and reach an accurate consensus on a proposal that needs to be confirmed. This paper further studies the PBFT consensus mechanism and its existing improved consensus mechanism and then proposes a new, improved PBFT mechanism: "Byzantine fault-tolerant consensus mechanism based on machine learning." A logical regression algorithm is used to predict whether the request is passed or not [10]. Data blocks are produced in advance and cached when the prediction is passed to wait for validation and reduce the delay. Then, the nodes in the system are dynamically classified by K-means clustering algorithm to ensure the regular operation of the anonymous trade transaction system.

The main contributions of this paper are as follows:

(1) In this paper, a data transaction and authentication protocol for anonymous data are being developed. The mapping relationship between the real identity and the false identity of the data owner is blinded and sent to the buyer when the seller sells the data. When a buyer wants to verify the seller's identity, the only way to do so is through blockchain authentication.

(2) In this paper, a machine learning-based Byzantine fault-tolerant consensus mechanism is proposed. All nodes in the system are initially classified into different types using K-means clustering and then reclassified as the number of nodes changes to ensure dynamic performance. A logistics regression algorithm is also used to predict validation results ahead of time, make full use of node idle waiting time, and reduce delay and resource waste.

The remainder of the paper is organized in the following manner. The background work is examined first in Section 2, followed by methodology in Section 3. The results and discussion are then presented in detail in Section 4. Finally, Section 5 concludes the paper.

2. Background

This section discusses the related work in the context of blockchain technology and anonymous storage transaction technology.

2.1. Blockchain Technology. Blockchain technology is proposed to solve the long-standing Byzantine general problem and the problem of double cost. In recent years, it has developed rapidly, and various kinds of digital currencies have emerged in an endless stream. For example, inspired by Bitcoin, a programmer at Google launched an improved version of the digital currency, Litecoin. The technical principle is the same as Bitcoin, but Litecoin is produced and traded on a different principle. In addition, Miers et al. [11] proposed the concept of Zerocoin based on the zero-knowledge proof cryptography principle. So far, there have been dozens of digital cryptocurrencies. In the future, not only in the field of digital cryptography but also in other fields blockchain will be fully developed.

So far, blockchain has proven to be successful not only in theory but also in practice. Vitalik proposed Ethereum, a single blockchain that allows for reprogramming to achieve arbitrarily complex computing functions, in 2013. Simply put, Ethereum is a smart contract-enabled public blockchain platform. More than 30 companies announced the Hyperledger Consortium Project in 2015, led by the world's largest open-source organization, the Linux Foundation. The goal of the project is to advance the development of blockchain and distributed ledger protocols. SuperLedger is a collaborative project that consists of subprojects for various purposes and scenarios, with a modular design, code readability, and long-term evolution path in mind. The SuperLedger community now includes over 140 businesses and organizations.

2.2. Anonymous Storage Transaction Technology. With the continued growth of the Internet, the number of terminal devices, servers, and users on the network is increasing. The amount of data produced is also on the rise. The question of how to protect these data and the data owner has become a focus of data security research. Furthermore, blockchain technology has cryptographic properties that allow one's identity to be protected without being revealed. As a result, current research is focusing on the combination of blockchain with anonymous storage and anonymous transactions. In terms of anonymous storage, Do and Ng [12] proposed a secure distributed data storage system with a keyword search service based on blockchain technology [13–15]. RSA [16] and the discrete logarithm hypothesis allow clients to upload data to cloud nodes in ciphertext form [17, 18]. While ensuring the availability of data, it also provides the data owner with the ability to grant others the right to search their data. Lu et al. [19] proposed a blockchain-based anonymous reputation system (BARS) to break the linkability between real identity and public key to protect privacy. Finally, Shafagh et al. [20] proposed a blockchain-based distributed access control and data management system for the Internet of Things, customized for IoT data traffic, and can achieve secure data sharing. Using blockchain as the storage layer, secure and flexible access control management is realized.

In terms of anonymous transactions, Heilman et al. proposed a solution to anonymity for transactions on and off the blockchain of Bitcoin. They have used an untrusted third party to issue anonymous credentials, which users can exchange into Bitcoin. The simultaneous use of blind signatures [21] and smart contracts ensures anonymity and fairness during the exchange of Bitcoin certificates [22]. Aitzhan and Svetinovic [23] do not rely on certificates but trusted third parties in distributed smart grid energy trading transaction security problems. They use blockchain technology, multiple signatures, and anonymous to encrypt the message flow to realize the concept of decentralized energy trading system validation. It allows peers to negotiate anonymous energy prices and trade safely. Wang et al. [24] introduced a blockchain-based mutual authentication and key agreement protocol for edge computing-based smart grid systems. Using blockchain, the protocol can support effective conditional anonymity and key management without the need for other complex cryptographic primitives.

3. Methodology

In this section, the following subsections attention-based graph convolution, third-order hourglass networks, and residual dense module are discussed in detail.

3.1. Data Anonymous Transaction and Authentication Protocol. After the edge device encrypts the data and stores the address on the blockchain, it makes a transaction request when a user demands the stored data. At this time, the edge device serves as the seller, and the user serves as the buyer. The protocol uses the elliptic curve public-key encryption system to ensure the anonymity of the transaction. The corresponding relationship between the real identity and the false identity mapping is blinded by the improved blind signature and sent to the buyer. Under normal circumstances, the buyer cannot know the corresponding real identity and can only obtain its real identity by blind-decoding it during arbitration, as shown in Figure 1.

There are four actors in this agreement: buyer, seller, blockchain, and bank. Each has different responsibilities and functions.

(1) Buyer: a buyer is a user who is interested in specific data and has the need to purchase data. When the buyer wants to purchase a certain type of data, the buyer will issue a transaction on the blockchain network. The labeled type of data that the buyer wants to purchase is declared. The amount used to purchase data is valid. In addition, the buyer's public key, PK_Buyer, and the parameter, eq_b, are used to prove his identity.

(2) Seller: in this agreement, the edge device as the seller transacts data with the buyer. Before the transaction, the seller will check the transaction request issued by the buyer in the blockchain network. Suppose the seller is willing to transact with one of the buyers. In that case, it will publish a transaction in the blockchain, claiming that it is willing to transact with the buyer. The seller can show the data type LABEL of the data he owns.

(3) Blockchain: as a trading platform for buyers and sellers, blockchain releases transactions on the blockchain to realize direct transactions between the two parties without the intervention of a third party. Meanwhile, all transaction records are searchable on the blockchain and cannot be tampered.

(4) Bank: when the seller and the buyer make a formal transaction, the buyer will issue a cheque. After receiving the cheque, the seller will send it to the bank. The bank will complete the transfer through the corresponding accounts of the seller and the buyer on the cheque.

The agreement is divided into the following stages:

(1) Peripheral device registration stage: peripheral device, as the seller, needs to register with the blockchain before selling data to obtain the right to trade with the buyer.

(2) Check generation stage: this stage mainly includes the buyer sending a transaction request to the blockchain. The seller agrees to trade with the buyer and obtains the check.

(3) Data transaction stage: after the seller gets the cheque signed by the buyer, he/she initiates a transfer request to the bank. The bank verifies his/her identity and transfers the corresponding amount of the buyer's account to the seller's account. After successful transfer, the bank informs the seller, and the seller sends the corresponding data to the buyer.

(4) Certification stage: the buyer thinks that the seller's selling data is wrong and requests the arbitrator for arbitration. Under the supervision of the arbitrator, authentication is carried out.

3.2. Consensus Mechanism Based on Machine Learning. This paper proposes a practical Byzantine fault tolerance based on machine learning [25–29] (MLPBFT). To begin, the mechanism divides the nodes in the system into three nodes with different responsibilities: customer node, master node, and supervision node, using the K-means clustering algorithm [30]. The client node is also the data block producer and request initiator in MLPBFT. The transit node, or master node, preprocesses and forwards the request initiated by the client node to the supervising node. The monitor node primarily verifies and confirms the messages it receives and then replies to confirm the message once the verification is complete. Finally, after the client node sends the request, the waiting time will be used to predict the probability of the request passing through the logistic regression algorithm [31]. Then, based on the prediction result, decide whether to produce the block ahead of time. In addition, the consensus process will be suspended when the number of nodes in the system changes, to ensure the system's dynamism. The data pairs of multiple groups of different classification types caused by a change in the total number of nodes will be calculated using the K-means clustering algorithm, and the appropriate classification will be chosen.

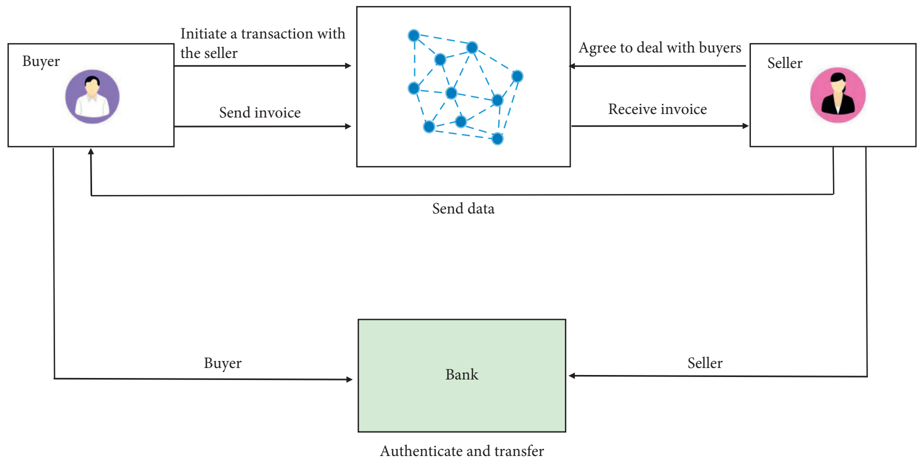

Figure 1: Model of the proposed protocol.

3.2.1. K-Means Algorithm. K-means is usually used to solve clustering problems and is a form of unsupervised learning [32, 33]. It is a clustering algorithm based on the distance between data. The distance between two data points is used as a criterion to judge whether the data is similar. The closer the distance is, the more similar the two data points are. The implementation steps are as follows:

(1) Suppose $D = \{d_1, d_2, \ldots, d_n\}$ is the training sample data, where $d_i = \{X_i, Y_i\}, 1 \leq i \leq n$. Select K data from D as the initial K cluster centers, $K < n$. Set the selected K initial cluster centers as $\{(X_1, Y_1), (X_2, Y_2), \ldots, (X_K, Y_K)\}$. Then, the remaining data is recorded as $\{(X_{K+1}, Y_{K+1}), (X_{K+2}, Y_{K+2}), \ldots, (X_n, Y_n)\}$.

(2) Use the Euclidean distance method to calculate the distance $\{r_1, r_2, \cdots, r_K\}$ from each data in the dataset to each cluster center and record it. The calculation equation is as follows:

$$r_i = \sqrt{(X - X_i)^2 + (Y - Y_i)^2}, \quad 1 \leq i \leq K. \tag{1}$$

(3) According to the recorded and calculated distance, select the smallest distance, namely, $\min\{r_1, r_2, \cdots, r_K\}$, and classify the data and the corresponding initial cluster center into the same category.

(4) When all the data are divided, there are K clusters of the data set. All the data in each category are recalculated to calculate the new clustering center. The calculation method is generally to select the arithmetic mean of each dimension of all the data in this cluster.

(5) Go to step 2 and continue to calculate and iterate until the iteration ends when the relationship between the initial cluster center and the new cluster center meets the preset threshold.

3.2.2. Consensus Mechanism. A PBFT improvement scheme using a logistic regression algorithm is proposed in this paper. The K-means clustering algorithm can easily manage with a faster convergence speed before the data changes are easier to update the model characteristics. The differences between clusters produce a better result, and all that is required is to adjust the number of clusters in the K MLPBFT scheme. The MLPBFT consensus mechanism divides the network's nodes into three categories: client node, master node, and supervision node, using a K-means clustering algorithm. Nodes fall into various categories, each with its own set of responsibilities. The consensus process is completed through two stages: the preparation stage and the verification stage. On this basis, MLPBFT will use the logistic regression algorithm to predict the verification result of the request made by the customer node, while the customer node is waiting for the reply message, and complete the production of the data block in advance, when the predicted result is passed. Moreover, the K-means clustering algorithm will be started again when the nodes change. The nodes in the system will be reclassified to ensure the system's dynamic. In addition to the characteristics of dynamic and security, MLPBFT also has certain advantages compared with the consensus in terms of time and energy consumption, throughput, fault tolerance, and communication times.

3.2.3. Consensus Process. The MLPBFT is similar to the VPBFT consensus process. Instead of the PBFT's "three-phase" model, the MLPBFT adopts a "two-phase" model, consisting of a preparation phase and a validation phase, as shown in Figure 2.

The customer node initiates the request for the production data block. The *request* message is Request: <Bcontent, Tc, Sc>, where Bcontent is the data block to be produced, Tc is the timestamp of the *request* message sent by the customer node, and Sc is the signature of the customer node. The data block is divided into two parts, the block and the data. The block contains the relevant information of the previous data block. If the block is a creative block, the information of the block only identifies the block as a creative block.

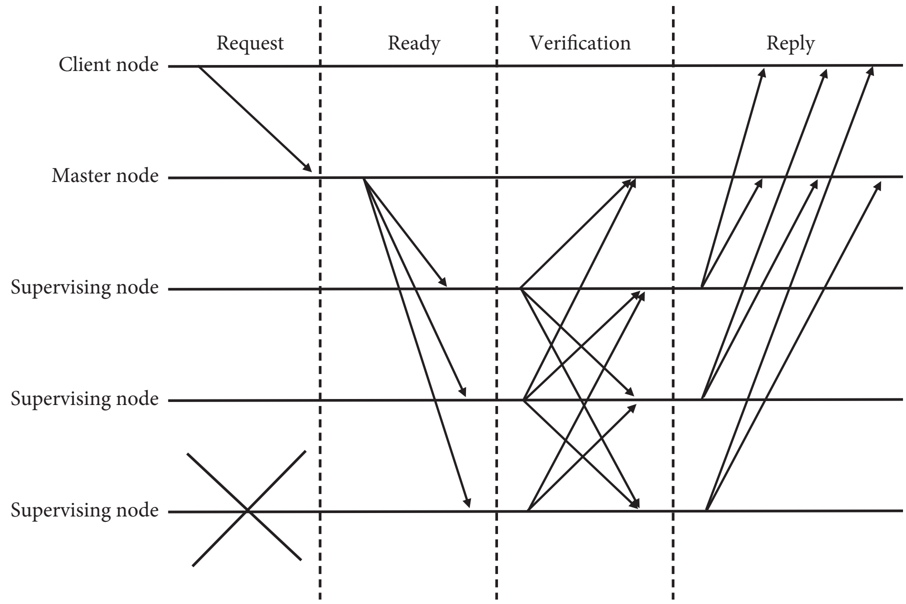

Figure 2: The consensus process of MLPBFT.

After the master node receives the *request* message, it first numbers the message and then extracts the message's important information. A summarized message is appended to the *request* message, then adds the timestamp and signature to form a *query* message, and then broadcasts the *query* message to all the supervising nodes. The *query* message is Query: <D, Tm, Sm>, where Num is the number, D is the abstract, Tm is the primary node's timestamp, and Sm is the primary node's signature. This stage is the preparation stage.

Monitoring nodes after receiving the master node to send over the query message, first verification, validation message contained within the request's specific content, and information are consistent. The master node is correct. Add validation results to Y; otherwise, add validation results to N. The valid form contains information of verification results. Supervisor nodes will broadcast *valid* messages to other monitoring nodes for mutual confirmation and verification. Valid:< ID, Num, Bcontent, Tc, Sc, D, Tm, Sm, Y/N>, where ID is the number of the monitor node itself. This phase is the validation phase.

When the supervisory node receives at least $1 + Ns/2$ (Ns is the number of supervisory nodes). A valid message with Y will reply to a confirmation message to the client node. The confirmation message is Commit: <ID, Num, Bcontent, Tc, Sc, D, Tm, Sm, Y/N, Ts, Ss>, where Ts is the timestamp added by the supervisory node and Ss is the signature of the supervisory node.

If the client node receives at least $1 + Ns/2$ Commit messages containing Y, it will be considered that the request was passed. The client node will directly chain the data block produced in advance according to the predicted result or produce the corresponding data block and chain it. Otherwise, the request was not approved. Discard the request and restart the request.

3.2.4. Dynamic Classification Based on K-Means. To conduct the initial type division of nodes in the system, the K-means clustering algorithm was started before the consensus process. The K-means clustering algorithm is triggered again when the total number of nodes in the system changes, automatically classifying all nodes in the system. They ensure that the system can continue to function without restarting after the number of nodes changes. The K-means clustering algorithm was chosen for two reasons. To begin, nodes in the MLPBFT consensus mechanism must be divided into three types, each with different responsibilities. The number of nodes of different types must be redivided when nodes join or leave. Second, the K-means clustering method is a more widely used clustering method, mainly used to complete data aggregation and classification. The algorithm is easy to understand and implement.

4. Experiments and Results

This section discusses experimental setup, data sets, evaluation methods, and experimental results discussed in detail.

4.1. Consensus Time-Consuming Analysis. Among the consensus mechanisms such as PBFT, VPBFT, K-PBFT, and MLPBFT, the consensus process is the most important. This experiment will simulate the consensus process of each consensus mechanism using a Python program in a network environment with fixed network bandwidth in order to compare the time consumed in the consensus process of these several consensus mechanisms. The consensus process, which is used in the experimentation process, starts with a consensus process and progresses over time. This time, all messages sent are serial transmissions, with the same data transmission resources and message size. At the same time, all consensus mechanisms are the same, with the same node number, data processing speed, and processing time. Figure 3 depicts the results of 10 experiments that were

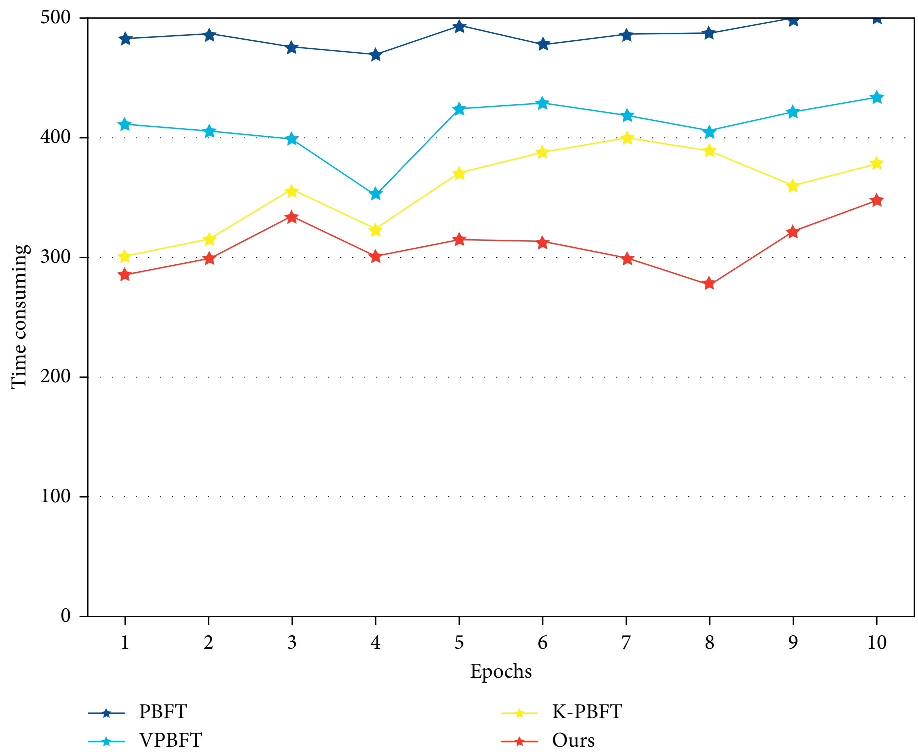

FIGURE 3: Time-consuming comparison results of the consensus process.

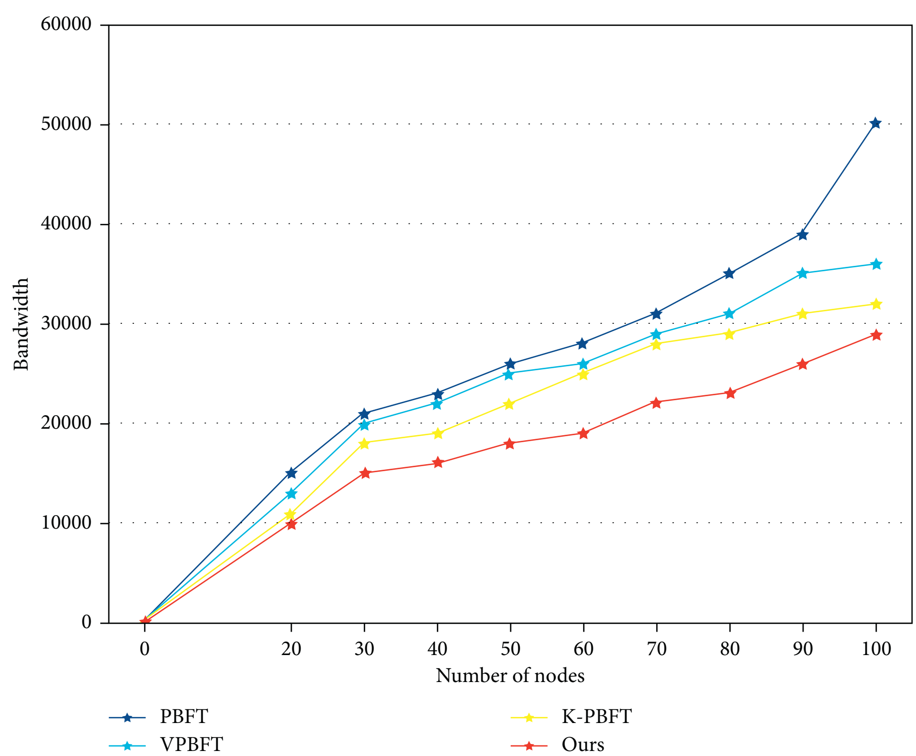

FIGURE 4: Comparison results of the bandwidth consumed by the consensus process.

conducted after simulating a consensus process of a consensus mechanism using Python and the program of the node itself.

As can be seen from Figure 3, under the same network environment and the same nodes, the time consumed by a consensus process of 1VB and PBFT is less than that of

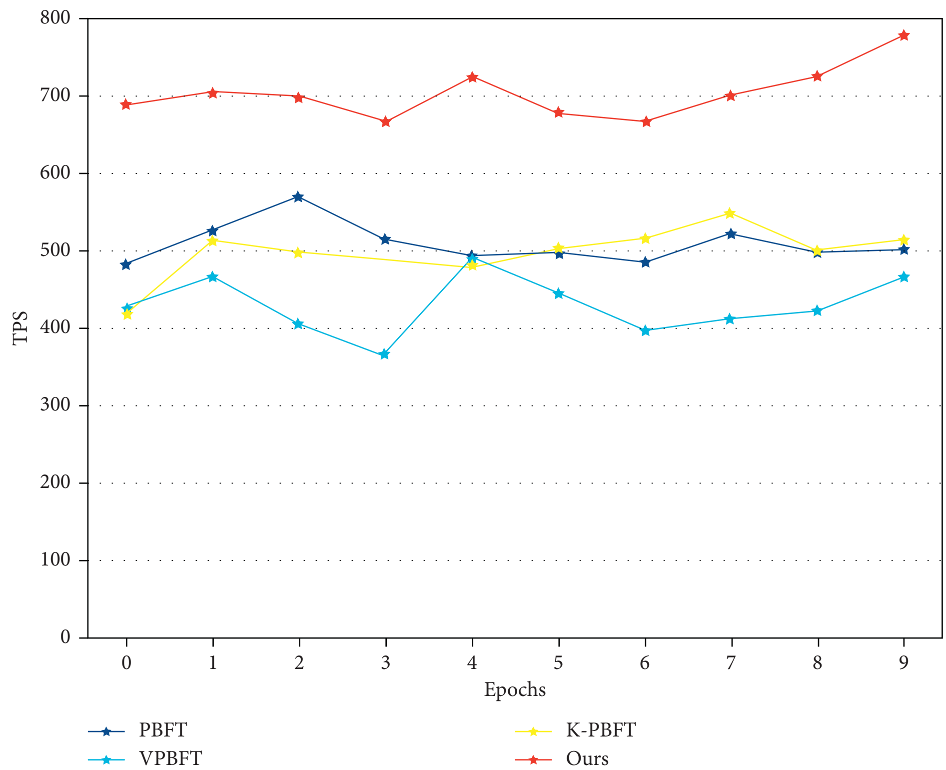

Figure 5: Comparative experiment results of throughput.

PBFT, VPBFT, and K-PBFT. For example, after calculating the average time of 10 experiments of each consensus mechanism, the average time of one consensus for MLPBFT was about 308.5 ms. In contrast, the average time of one consensus for PBFT, VPBFT, and K-PBFT was 484.8 ms, 409.4 ms, and 357.2 ms, respectively.

4.2. Bandwidth Usage Analysis. In the improvement scheme MLPBFT proposed in this paper, the consensus process is divided into a preparation phase and a verification phase. In the preparation phase, the master node needs to broadcast the entire network to send the query message to the supervisory node. The supervisory node needs to broadcast the valid message to other supervisory nodes for mutual confirmation and verification in the verification phase. Thus, it can be seen that the total network bandwidth required for the entire consensus process is twice the bandwidth.

It can be seen from Figure 4 that the network bandwidth consumed by the MLPBFT in the consensus process is lower than that of PBFT, K-PBFT, and VPBFT, which proves the superiority of this algorithm.

4.3. Throughput Analysis. One of the most important indicators for evaluating the benefits and drawbacks of the consensus mechanism is throughput. It is measured in transactions per second (TPS) and has the following calculation equation:

$$\mathrm{TPS} = \frac{\mathrm{SUM}\,(\text{transactions})}{T}, \quad (2)$$

where T is the time interval from when a transaction is issued to when a consensus is reached to generate a block, and SUM (transactions) is the total number of transactions included in the block generated in this time interval.

Figure 5 shows that the average throughput of MLPBFT is around 702.1 per second for the same number of nodes. It has a throughput of 194.12 per second, 175.64 per second, and 253.11 per second, respectively, which is higher than PBFT, VPBFT, and K-PBFT.

5. Conclusion

For some existing consensus mechanisms, there are still some problems in various aspects. This paper proposes a trade transaction protocol algorithm based on the blockchain consensus mechanism. First, in response to the lack of dynamics of PBFT, we proposed to introduce a voting mechanism in VPBFT. This mechanism divides the nodes into four types with different responsibilities and gives the number relationship between the nodes. When the number of nodes changes, it can be calculated according to the number relationship to ensure dynamicity. Second, a data anonymous transaction and authentication protocol is designed. In the agreement, when the seller sells the data, the mapping relationship between the real identity and the pseudoidentity of the data owner is blinded and sent to the buyer. When the buyer wants to verify the identity, the seller's identity can only be verified under the authentication of the blockchain. After experimental testing and simulation analysis, the algorithm in this paper is superior to existing methods in terms of consensus time-consuming, energy consumption, throughput, and fault tolerance.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

The Research of Convolutional Neural Network Based on Integrated Classification in Question Classification

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As a new generation of search engine, automatic question answering system (QAS) is becoming more and more important and has become one of the hotspots of computer application research and natural language processing (NLP). However, as an indispensable part of the QAS, the role of question classification is an understood thing in the system. In view of this, to further make the performance of question classification much better, both the feature extraction and the classification model were explored. On the study of existing CNN research, an improved CNN model based on Bagging integrated classification ("W2V + B-CNN" for short) is proposed and applied to question classification. Firstly, we combine the characteristics of short texts, use the Word2Vec tool to map the features of the words to a certain dimension, and organize the question sentences into the form of a two-dimensional matrix similar to the image. Then, the trained word vectors are used as the input of the CNN for feature extraction. Finally, the Bagging integrated classification algorithm is used to replace the Softmax classification of the traditional CNN for classification. In other words, the good of W2V + B-CNN model is that it can make use of the advantages of CNN and Bagging integrated classification at the same time. Overall, the new model can not only use the powerful feature extraction capabilities of CNN to extract the potential features of natural language questions but also use the good data classification capabilities of the integrated classification algorithm for feature classification at the same time, which can help improve the accuracy of the W2V + B-CNN in the application of question classification. The comparative experiment results prove that the effect of the W2V + B-CNN is significantly better than that of the CNN and other classification algorithms in question classification.

1. Introduction

In the Internet age, information has exploded. In the face of massive fragmented information, people's desire to quickly obtain accurate and concise information has become more and more urgent, and the QAS has emerged at the historic moment. Unlike traditional search engines, QAS is a high-level form of information retrieval, which has become a hot focus in the field of current natural language. It allows users to describe the problems in natural language and can find or infer the answers to the users' questions from massive heterogeneous data and then submit them to the users. For example, for the question "What color is the skin of Chinese people," the system will give the answer directly as "yellow." It greatly improves the users' query efficiency and better meets the users' needs. The QAS generally includes three main parts: question analysis, information retrieval, and answer extraction [1], and each part cooperates with each other to efficiently obtain the target information required by the user. If question analysis is the cornerstone of QAS, then question classification is not only one of the key parts of question analysis but also an indispensable module of the QAS. It not only helps to optimize the performance of the system, such as reducing the search space of candidate answers and the time to locate the correct position of answers, but also helps to formulate answer extraction strategies. It can be seen that the result of question classification can provide useful guidance information for other modules of the system, and its accuracy will have a direct influence on the quality of the whole QAS. Therefore, it can be said that the research on question classification has important practical significance and has a positive influence on improving the quality and performance of QAS.

Question classification is to determine the type of question associated with the characteristics of the answer or the semantic information of the question under a certain classification standard. Currently, with the persistent maturity and improvement of its research, it has also attracted much attention in the field of NLP. The essence of question classification is short text classification. The current research on it is generally based on the idea of text classification and combined with the characteristics of question classification itself. But different from ordinary text classification, question classification contains unique word feature information. How to fully mine this information is the key to question classification. There are two types of traditional question classification methods: rule-based methods and statistical machine learning methods. Early rule-based methods mainly used artificial analysis of the syntactic structure to extract rules and then judge the question type [2, 3]. This kind of method has many advantages. For example, it is relatively easy to implement and does not need a lot of training data, so the classification speed is fast. But the disadvantage is that these methods rely more on experts and are subjective. Moreover, the classification decision of experts is very easy to be affected by the classification system, which makes it less flexible. Subsequently, the methods based on statistical learning showed a good classification effect, which have the advantages of strong versatility, easy transplantation, and expansion [4, 5]. The machine learning models based on statistical methods commonly used in question classification are Bayes [6], SVM [7, 8], KNN [9, 10], ME [11], and so on. However, the disadvantage of the statistical learning method is that its classification accuracy is still easily affected by the accuracy of syntactic analysis.

Recently, with the wide application of deep learning technology in the field of NLP, its characteristics of not relying on complex feature engineering and fully mining the feature information of natural language have attracted the interest of a large number of scholars. They began to use deep learning methods to classify questions. Therefore, question classification methods based on deep learning technology came into being. Different from the previous classification methods, the DNN model has significant advantages in question representation and feature extraction. The multilayer network structure can abstract the original question sentence into a high-level vector representation so that the dimension of the feature vector becomes higher and the classification accuracy is greatly improved. Meanwhile, with the wide study of word vector technology and deep neural network technology, people have more new ideas in NLP tasks. Among the deep neural networks applied to NLP tasks, the most commonly used ones are RNN and CNN. Among them, CNN is a typical spatial deep neural network. It has significant advantages in feature extraction and is good at feature self-extraction, which can reduce the difficulty of feature extraction to a certain extent in question classification and improve the accuracy of classification. Based on this, it has inspired researchers to use CNN as one of the commonly used architectures in the application of deep learning in question classification. Many methods based on CNN have been proposed and a large number of research results have emerged [12, 13]. Therefore, there is still a lot of research space for question classification with deep learning, which is worthy of further research.

2. Related Work

2.1. Question Classification. The purpose of question classification is to classify questions into corresponding semantic classes according to the type of answer. As a key link of the question answering system, it has an important guiding role for subsequent answer extraction modules, and it also has a very important significance for the QAS [14]. The so-called question classification means that, under a certain classification system, for questions that are not marked with a class, the system automatically classifies the relevant class of the question according to the content of the question. This correspondence can be abstracted as a mapping process in a mathematical sense, which can be represented by the following mapping function [15]:

$$R: X \longrightarrow \{C_1, C_2, \ldots, C_N\}, \tag{1}$$

where X represents a set of question samples and $\{C_1, C_2, \ldots, C_N\}$ represents a set of question classes. R is responsible for mapping the question $x \in X$ of the unknown class to a class C_i according to a certain rule or a certain classification algorithm.

However, the current methods based on question classification research usually draw on ideas of text classification. The difference between them is that common words such as "what" and "is" are often overlooked in text classification, but these words that may be used as stop words are often very important in question classification. This is also one of the characteristics of question classification. What the two have in common is that they both analyze the information contained in the text and combine the characteristics of question classification to classify the questions into their categories. Based on the ideas of text classification, the question classification process can be described as shown in Figure 1, which specifically includes the division of training set and test set, preprocessing, feature extraction, classifier training, classification prediction, and others [16]. For Chinese text, data preprocessing includes Chinese word segmentation, part-of-speech tagging, and stop word removal. The advantage of feature extraction is that it helps to reduce the complexity and improve the accuracy of question classification by extracting better feature information from the original samples. Common methods include TF-IDF calculation, n-gram, Word2Vec, and LDA. Since question classification is generally a multiclass model, machine learning generally uses methods like Bayes, KNN, and SVM for classification. The flowchart of the question classification process is shown in Figure 1.

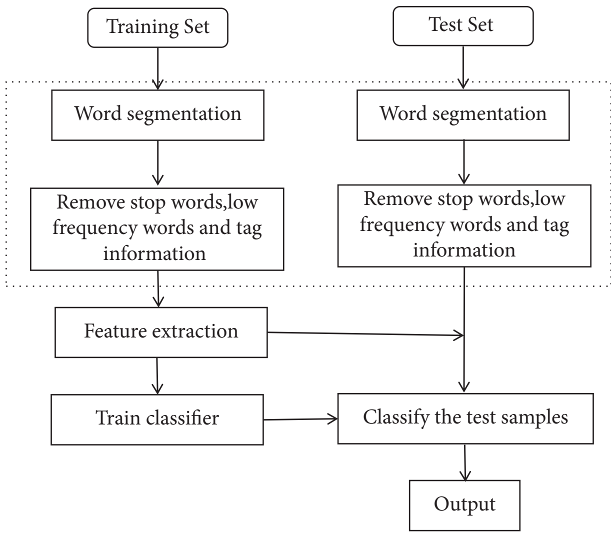

Figure 1: The flowchart of the question classification process.

2.2. Question Classification Based on Deep Learning. The concept of deep learning was first proposed by Hinton and Salakhutdinov [17] and others in 2006. It stimulates the mechanism of the human brain and can extract features layer by layer from the original data. To a large extent, it is helpful for solving the problems of time-consuming, laborious, and poor effectiveness that often occur in traditional machine learning methods which need to customize feature extraction rules by themselves. In recent years, with continuous development of deep learning technology, its application value in the fields of image processing [18], pattern recognition [19], and NLP is self-evident. For question classification tasks, deep learning can be used to actively analyze and learn the syntactic and semantic features implicit in the questions. This helps us to analyze the semantic feature structure of the question at a deeper level and perform feature extraction, so as to make the question classification more accurate. Unlike traditional machine learning methods, deep learning does not require manual extraction of the characteristics of question sentences, which greatly reduces labor and time costs. It can automatically obtain basic features, then combine these basic features into complex features, and finally train the model to judge the semantic relationship between question features and question classes. Therefore, the method based on deep learning has faster data processing capabilities and strong adaptive deep learning capabilities. Meanwhile, its fault tolerance and noise resistance are relatively high, which is very suitable for question classification.

Currently, the most representative models in deep learning for question classification are CNN model, long short-term memory network (LSTM) model, and Bi-LSTM model. What is more, a large number of relevant research results have also emerged. Kim et al. introduced a sentence classification method with a convolutional neural network based on word vectors in 2014. They used CNN to classify English questions by turning question sentences into word vectors [20]. After that, Zhang et al. further improved Kim's model and proposed a novel low-complexity model termed CNN-BiGRU [21]. They introduced the bidirectional gated recurrent unit (BiGRU) into the traditional CNN model to naturally learn the question sentence and achieve classification. It improves the classification accuracy of the CNN model on a variety of English classification data sets. Kalchbrenner et al. [12] constructed a Dynamic Convolutional Neural Network (DCNN). In the network, they used a global k-max pooling operation to solve the problem of inconsistent question length, used the DCNN network to simulate the semantic information of the question, and achieved a better question classification effect. Le and Zuidema studied the problems of incorrect modification of syntactic components and incorrect conversion of syntactic tree in the question classification of Recurrent Neural Network (RNN). They used the syntactic forest as the input of the CNN network, proposed the Forest Convolutional Network (FCN), and achieved good results in the question classification task [22]. Nan et al. constructed a neural network model based on LSTM to complete the joint modeling of the description subject and the description text and achieved a good classification effect [23].

Inspired by the above research, we started research from two aspects of feature extraction and classification model. On the basis of CNN, we further integrated the advantages of the Bagging classification algorithm, proposed an integrated convolutional neural network model, and applied it to the problem classification. The specific research content is as follows:

(1) Firstly, we use Word2Vec and CNN to complete the feature representation and feature extraction of question sentences. Since the question contains fewer words, the traditional vector space model may cause problems, such as the feature latitude that is too high and or feature vector data that is sparse. Moreover, since the correlation between words and the position information of the words in the document is not considered, these factors will affect the accuracy of question classification. Therefore, we combine the characteristics of short texts, use the Word2Vec tool to map the features of the words to a certain dimension, organize the question sentences into the form of a two-dimensional matrix similar to the image, and then set the matrix as the input of the CNN. Then, we design the CNN model and complete the feature extraction of the input data through operations such as convolution and pooling.

(2) Based on the study of the CNN model, the Bagging algorithm is used to construct the classification layer. Aiming at the problem of weak generalization ability caused by the Softmax classifier used by most convolutional neural networks at present, we propose a B-CNN integrated model combined with the Bagging algorithm to improve the accuracy and generalization of question classification.

(3) Finally, to verify the effectiveness and feasibility of the new model in question classification, several

experiments were conducted in the Chinese question set provided by the Information Retrieval Laboratory of Harbin Institute of Technology. The results prove that the effect of the W2V + B-CNN model on question classification is significantly better than that of the CNN and other classification algorithms.

3. Question Classification Model of CNN Based on Bagging Integrated Classification

To optimize the accuracy of the CNN model in processing multiclassification of questions, the paper further combines the advantages of the Bagging algorithm on the basis of the CNN and proposes an integrated convolutional neural network model referred to as W2V + B-CNN. Meanwhile, we apply it to question classification. The basic principle of W2V + B-CNN is to express the question as a word sequence with words as the unit and map it to a multidimensional vector to construct a set of word vectors. Furthermore, the characteristic information in the question is extracted through the integrated neural network, so as to realize the question classification. The structure diagram of the W2V + B-CNN model used in question classification in this paper is shown in Figure 2.

In Figure 2, we can see that the model is mainly composed of three layers, namely, the word vector matrix input layer, the convolutional feature extraction layer (including convolution layer and maximum pooling layer), and the integrated classification layer (including Dropout and Bagging integrated classification output). The word vector matrix input layer uses the Word2Vec tool to train the input sentence, converts the words into word vectors, and then splices them into a text word vector matrix. The convolution layer uses the convolution kernel to perform convolution operation on the input feature vector to extract features. The pooling layer performs sampling processing on the features extracted by the upper layer and retains important features in the form of filtering. In the integrated classification layer, the pooled and spliced feature vectors should be dropout processed during model training. Finally, the Bagging integrated classifier is used to complete the mapping of the feature vector to the category, so as to obtain the final classification result.

3.1. Word Vector Matrix Input Layer. Word vector can also be called word embedding technology, which can map words containing rich semantic information to abstract high-dimensional vector space. It is a method of continuous digital vectorization of words using a shallow neural network [24, 25]. The advantage of word vector technology is that it is helpful in solving the problem of data sparsity in traditional question classification methods. In the research of a large number of word vector learning methods, Mikolov and others from Google open-sourced a tool for generating word vectors called Word2Vecor in 2013, which includes two models of CBOW and Skip-gram [26, 27]. The structure of the two models is shown in Figure 3. The modeling idea of CBOW is to use the words in the window to predict the central word, while the modeling idea of Skip-gram is to use the central word to predict the surrounding words. In our study, the Skip-gram model will be chosen to train word vectors.

Assume that, after training, each question S can be represented by a word vector matrix, that is, $S = \{s_1, s_2, \ldots, s_n\}$, where s_i is the ith word of question S and n represents the number of words contained in S. Each word s_i can be represented by a word vector, that is, $\{w_1, w_2, \ldots, w_k\}$, where w_i is the weight of the ith dimension in the word vector and k represents the dimension of the word vector. Two models of CBOW and Skip-gram are shown in Figure 3.

3.2. Convolutional Layer. The convolutional layer is the core component of the CNN, and the core point is to capture the local correlation. Specifically for question classification tasks, the convolution kernel can extract key information similar to N-grams in the sentence. The convolution operation in the text is somewhat different from the convolution operation in the image. Because a word vector is a whole in the text, it makes sense to perform a convolution operation on the whole word vector. Therefore, assuming that the dimension of the word vector is k, then the width of the convolution kernel should also be k. When convolution operation is performed on the sentence $S = \{s_1, s_2, \ldots, s_n\}$, the convolution kernel W can be expressed as $W \in R^{hk}$, and h is the height of the convolution kernel. Then, every time you slide a word vector matrix with length h and width n, you will get an eigenvalue. The calculation formula of the eigenvalue is

$$d_i = f\left(S_{i:\, i+h-1} \cdot W + b\right), \quad (2)$$

where b is a bias term, $S_{i:\, i+h-1}$ is a word sequence of length h, namely, $(s_i, s_{i+1}, \ldots, s_{i+h-1})$, and f is an activation function. Commonly used activation functions include tanh, ReLU, and sigmoid. Increasing the activation function can make the model introduce nonlinear factors, so as to better fit the data. And the ReLU activation function will be applied in our study. After the entire question sentence is subjected to convolution operation, several feature vectors representing the sentence can be obtained:

$$D = \left(d_1, d_2, \ldots, d_{n-h+1}\right). \quad (3)$$

Because convolution kernels of different sizes can extract the features of questions from different angles, the feature information extracted by the convolution layer is affected by the size of the convolution kernel.

3.3. Pooling Layer. The pooling layer can reduce the dimensionality of features by downsampling the output vector of the convolutional layer. On the one hand, it can speed up the calculation, and on the other hand, it can effectively prevent the problem of simulation overfitting. In this paper, the maximum pooling method is used to process the feature vector D obtained by the convolutional layer, so as to select the most representative feature. The formula is

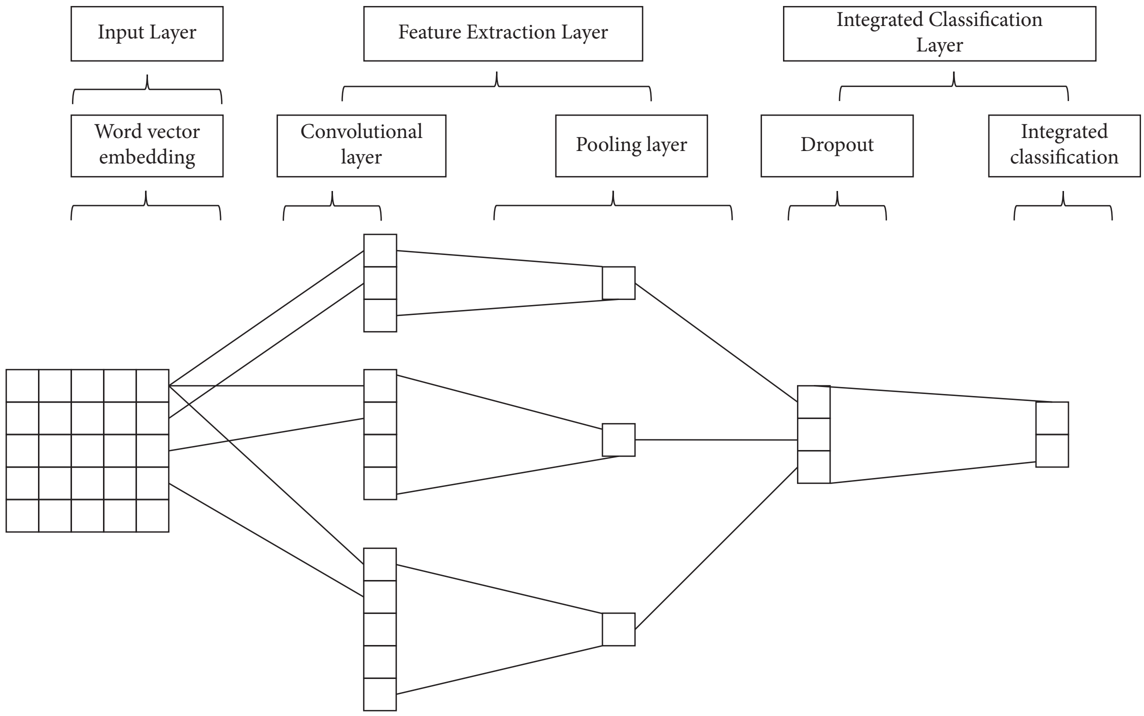

FIGURE 2: The structure diagram of the W2V + B-CNN model.

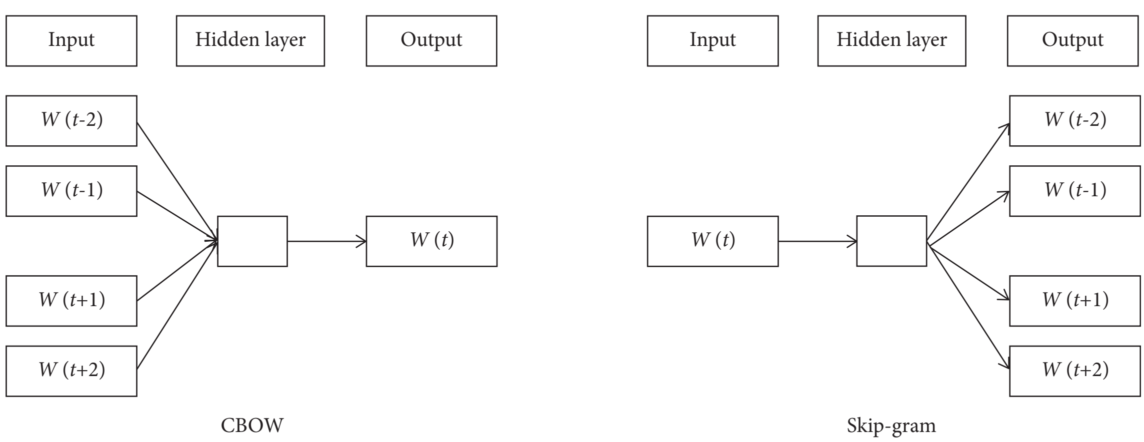

FIGURE 3: Two models of CBOW and Skip-gram.

$$D_{\max} = \max(D). \tag{4}$$

3.4. Integrated Classification Layer

3.4.1. Dropout. To avoid the problem of overfitting in the process of training, the Dropout operation is usually used to prohibit some hidden nodes from participating in forward propagation. These neurons will not participate in the update process so that the update of the weight will not rely on the role of the fixed nodes.

3.4.2. Bagging Integrated Algorithm. To further optimize the classification ability of the CNN, the Bagging integrated algorithm with better classification performance will be utilized to replace the Softmax classification function in the CNN. In the integrated classification layer, we will first apply the trained features of the convolutional layer and pooling layer as a new feature set, then input them into the Bagging integrated learning classifier for training, and finally output the classification results according to the voting method. In this way, CNN can be used to extract the potential features of the data set, and the integrated learning can be used for feature classification, which can help improve the accuracy of multiclassification tasks.

Suppose that, after the Dropout operation, the data set input to the integrated classifier is $D = \{(x_1, y_1), (x_2, y_2), \ldots, (x_m, y_m)\}$. Define $Y = \{-1, +1\}$ as the set of classification labels, T represents the number of base classifiers, and L represents the base classifiers. The hypothetical function after integration with the Bagging method is

$$H(x) = \arg\max_{y\in Y} \sum_{l=1}^{T} sign\left(\sum_{i=1}^{T} h_i(x) = y\right), \tag{5}$$

where $h_i\,(i = 1, 2, \ldots, T)$ represents the bootstrap distribution and its formula is

$$h_i = \frac{L(D, D_{bs})}{D_{bs}}. \tag{6}$$

4. Experimental Results and Analysis

4.1. Experimental Data. To verify the performance of the W2V B-CNN model, we designed several experiments on the Chinese question set provided by the Information Retrieval Laboratory of Harbin Institute of Technology. It is a relatively classic Chinese question classification data set with good universality and can better prove the performance of the algorithms. The classification system of the question set is divided into 7 classes, including description (DES), human (HUM), location (LOC), number (NUM), object (OBJ), time (TIME), and unknown (UNKNOWN). Each class contains some unique subclasses, so the data set has a total of 84 subclasses. Since there are no instances of UNKNOW type in the question set, we do not consider this class. The question set contains 6260 questions. During the experiment, we took 4960 of them as training samples and 1300 as test samples. The distribution of samples is shown in Table 1.

4.2. Data Processing. After the training sample set and test sample set are determined, these data need to be preprocessed. First of all, the preprocessing of the data includes format conversion, filtering punctuation marks, and special characters. Secondly, for the Chinese question data set, word segmentation is required. In the experiments, we can convert each Chinese question sentence into a sequence of words separated by spaces with the JIEBA word segmentation tool. Then, for Chinese question sentence, stop word removal processing is also needed. Stop words refer to words that often appear in the text without an actual meaning. The stop word list provided by the Harbin Institute of Technology is applied for follow-up experiments. The stop word list includes numeric characters, special characters, and commonly used nonsense words. Finally, the word vector training is carried out on each question sentence.

4.3. Evaluation Standard. In the experiment, we applied the classification accuracy (Acc) to judge the performance of the model, and its formula is defined as follows:

$$\mathrm{Acc} = \frac{\mathrm{AccNum}}{\mathrm{TNum}}, \tag{7}$$

where AccNum represents the number of questions in the test set that are classified correctly and TNum represents the total number of questions in the test set.

Table 1: The number of samples in training set and test set.

Class	DES	HUM	LOC	NUM	OBJ	TIME
Training set	797	328	882	1089	1274	590
Test set	159	177	370	241	198	155

4.4. Experimental Design and Result Analysis

4.4.1. Set Experiment Parameters. We know that traditional CNN training uses a gradient descent method. Generally speaking, although the batch gradient descent method can find the optimal solution, all the total samples are required to participate in the operation when the weight is updated, which will cause a large number of calculations and a slow convergence speed. As for the random gradient descent method, its advantage is that it only needs one sample to participate in the operation each time, and the convergence speed is fast. The disadvantage is that it falls into the local optimal solution easily. So we use the minibatch method for training in the experiments. In this way, the network can speed up the training speed while finding the optimal solution as much as possible to reduce the training loss. We set the minibatch size to 50. When training the word vector, each Chinese question is taken as a line to learn the word vector. And the Skip-gram model of the Word2Vec tool was applied during the process. The dimension parameter d of the word vector was set to 300. In addition, we also set other basic parameters in the experiment, the size of the convolution kernel sliding window is set to 5, and the dropout rate is set to 0.5.

4.4.2. Experimental Results and Analysis.

Experiment 1. Verify that the feature extraction method based on Word2Vec is better than traditional methods in Chinese question classification.

To verify the effect of different feature processing methods on classification, we carried out comparative experiments among the Word2Vec method, the bag of words method, the mutual information, and the IF-IDF method. In the experiment, 2480 pieces of data in the training set were randomly selected as training data, and 650 pieces of data in the test set were used as test data. The classification results are shown in Table 2.

The results in Table 2 prove that, compared with the traditional feature extraction methods, the method based on the Word2Vec has a higher accuracy rate. The main reason is that the feature vectors obtained by training and learning with word vectors can overcome the problem of data feature sparseness in traditional feature training methods. It helps alleviate the dimensionality disaster and high computational complexity. In addition, it can also help improve the accuracy of question classification and reduce the computational complexity of the model.

Experiment 2. Verify that the CNN based on Bagging integrated classification is better than traditional machine learning methods and CNN in Chinese question classification.

Table 2: Classification results based on different feature training methods.

Method	DES	HUM	LOC	NUM	OBJ	TIME	Total
Bag of words	72.87	56.74	64.31	75.16	64.25	60.48	65.67
Mutual information	70.43	54.84	60.66	72.57	62.40	58.16	63.26
IF-IDF	73.95	59.57	64.41	76.35	66.53	62.36	67.82
Word2Vec	79.32	65.95	73.64	84.53	73.06	69.57	74.71

Table 3: Comparative experimental results of different models.

Models	DES	HUM	LOC	NUM	OBJ	TIME	Total
Bayes	85.41	69.28	75.63	87.82	77.58	73.14	78.20
SVM	86.20	68.74	76.48	88.24	77.82	74.15	78.73
CNN	84.65	71.38	78.82	87.64	78.43	74.48	80.81
W2V + CNN	86.46	78.54	79.23	89.17	79.35	77.79	82.62
W2V + B-CNN	88.57	80.24	84.72	92.47	83.18	82.74	85.67

To verify the performance of the W2V + B-CNN model in the application of question classification, comparative experiments were conducted with traditional machine learning methods such as Bayes and SVM, as well as deep network models such as CNN and W2V + CNN. The comparative results are illustrated in Table 3.

From Table 3, the following conclusions can be drawn:

Conclusion 1. The results of Table 3 illustrate that the W2V + B-CNN model proposed in the paper has the best classification effect. Compared with traditional machine methods and CNN models, the W2V + B-CNN model has significantly improved classification accuracy both in the major class and in each subclass. Finally, the experimental results prove the effectiveness and feasibility of the W2V + B-CNN model in question classification.

Conclusion 2. In Table 3, we can also see that the question classification methods based on the CNN model are better than the machine learning method on the task of question classification. It shows that, for the distributed feature representation of word vectors in the task of Chinese question classification, using machine learning methods to construct and match features is not as advantageous as using CNN. The main reason is that the CNN can reduce the parameters of the model through local perception and weight sharing, thereby effectively reducing the complexity of the model. Meanwhile, the classification accuracy of the CNN models is higher than other machine learning models, which shows that CNN performs very well in the classification of Chinese questions.

Conclusion 3. We can also draw the conclusions from Table 3 that, compared with the CNN model, the classification accuracy of W2V + CNN model and W2V + B-CNN in each class has been improved. What is more, the classification accuracy of the W2V + B-CNN model has improved significantly. The reason is that, because the question contains fewer words, the problems of too high feature latitude and sparse feature vector data will occur when the traditional vector space model is used. Moreover, since the correlation between words and the position information of the words in the sentence are not considered, these factors will affect the accuracy of question classification, and the classification effect of CNN is not very satisfactory. Therefore, compared with SVM and Bayes learning methods, the accuracy of the CNN model has a relatively small improvement. Combining the characteristics of short texts, we took the Word2Vec tool to map the features of the words to a certain dimension, then organize the question sentences into the form of a two-dimensional matrix similar to the image, and use it as the input of the CNN model. The advantage is that it solves the data sparsity problem in traditional question classification methods and greatly improves the classification accuracy.

Conclusion 4. Comparing the W2V + CNN model with the W2V + B-CNN model, it can be found that the W2V + B-CNN model can further combine the advantages of the Bagging algorithm and has a greater degree of improvement in classification accuracy than the W2V + CNN model.

In summary, the W2V + B-CNN model proposed in this paper combines the idea of integrated classification with CNN. In this way, the CNN can be used to extract the potential features of the natural question, and the Bagging algorithm can also be utilized to optimize the classifier in the new model. It not only strengthens the positive influence of more complete data on classification but also weakens the negative influence of noisy data, thereby greatly improving the classification performance of the algorithm.

5. Conclusion

Question classification is a key link in the QAS, and its classification performance has an important impact on subsequent document retrieval and answer extraction. It can be said that, as an important submodule of the QAS, the importance of question classification is self-evident. Therefore, to optimize the performance of question classification, we conducted a certain research on the application of CNN and proposed a new model based on the Bagging integrated classification called W2V + B-CNN. Firstly, the model uses Word2Vec for word vector training and then uses the convolutional layer and pooling layer of the CNN for feature extraction and feature selection. Finally, in the integrated classification layer, the Bagging algorithm with better classification performance was used to replace the Softmax classifier for feature classification. On one hand, the new model can apply the CNN to extract the potential features of natural questions. On the other hand, it can also take advantage of integrated learning for feature classification. In the end, to fully verify the feasibility and effectiveness of the W2V + B-CNN model applied to question classification, we conduct comparative experiments with traditional machine learning algorithms and CNN. The results prove that, compared with other algorithms, the improved W2V + B-CNN model has higher classification accuracy and better question classification performance.

Data Availability

The labeled data sets used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

Attitude Perception of Badminton Players Based on Mobile Edge Computing

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In order to help badminton players make reasonable training plans and realize a comprehensive grasp of the training process, this paper mainly recognizes and perceives the posture of badminton athletes based on the method of moving edge calculation. Firstly, from the perspective of moving edge motion analysis, considering the vector field formed by moving edge vector as movable spatial distribution information, the spatial distribution model of moving edge field is realized. Secondly, while athletes interact with the computer through limb movement, the overall posture of athletes is divided into several parts, and each part is perceived separately. Finally, in the human posture evaluation module, an algorithm for human posture evaluation in the image pixel plane is proposed. Through comparative experiments, the motion recognition algorithm can effectively recognize the three typical swing movements of badminton players in the video and improve the overall performance of the existing recognition algorithms.

1. Introduction

Collecting data in sports and analyzing the data to complete posture perception is a hot spot in the intellectualization of the sports industry in recent years. In badminton competitions, athletes' attitude perception information can become an important semantic clue to understand the competition process, discover technical details, and extract highlights [1, 2]. In terms of the fineness of visual content analysis, the movement trajectory information of badminton players can be regarded as a coarse-grained description, which is the macroperformance of the whole game. The attitude perception of badminton players can be regarded as a fine-grained description, which can embody the details of the game [3, 4]. In order to analyze and understand sports video content in more detail, it is necessary to identify athletes' actions and collect the training information and posture information of athletes, so as to reasonably formulate the training arrangement [5]. On the basis of a large number of data analyses, we can realize a comprehensive grasp of the sports training process.

There are two main research directions of attitude perception. One is attitude perception based on inertial sensors. For example, in literature [6], three-axis acceleration sensors are used to collect user action data, and gesture recognition is realized for time-series modeling based on the Hidden Markov model. Literature [7] uses principal component analysis to perceive human posture based on the data collected by the three-axis acceleration sensor. The other is to use video surveillance and image processing for gesture perception. For example, in [8], for the complex environment, depth image technology is used for gesture recognition, and the average recognition rate of gesture can reach 98.4%. In racket motion recognition based on image and video data acquisition, [9] established an event hiding Markov model with binary classification according to the position of players on the court. Literature [10] proposed a badminton game data mining method based on two-dimensional sequence images. Literature [11] classifies the badminton shot of the compressed video and identifies the type of attack ball by detecting the badminton trajectory. Among the research topics based on badminton, most of them focus on the relationship between racket speed and ball speed, the prediction of ball speed, and the monitoring of players' state characteristics. There are few studies on the detection, analysis, and training of controlled steps for the classification, recognition, and training of hitting movements. The hitting action and controlled step are two important parts of badminton technology. By analyzing different hitting actions and comparing the hitting action characteristics of athletes with different technical levels, it is an important way to improve badminton skills.

This paper will take badminton game video as the research object to track and recognize the badminton players' swing in time-series images. Based on the idea of local motion vision analysis and grid classification, this paper proposes a motion descriptor based on moving edge calculation and constructs an athlete's attitude perception and evaluation algorithm to classify and recognize three typical swing movements of badminton players [12]. The first part is the introduction, which mainly introduces the research significance and research status at home and abroad. The second part is the swing motion perception based on moving edge calculation, which mainly focuses on the perception, segmentation, and recognition of badminton players' swing motion. The third part is the posture evaluation of badminton players, which mainly evaluates the perception of human posture, which helps athletes improve the standard of movement. The fourth part is the experimental results and analysis, and the fifth part is the summary and prospect of the full text.

2. Swing Motion Perception Based on Moving Edge Computing

Athletes' three-dimensional posture perception technology is the basis of realizing sports training auxiliary systems. In order to carry out a three-dimensional simulation of athletes' movement posture, so as to adjust the training mode and improve the training level, this paper studies the application of the unmarked three-dimensional posture perception method in a training assistant system [13, 14]. While the athletes interact with the computer through limb movement, they adopt the method of partial estimation, that is, the athletes' overall posture is divided into multiple partial postures, and each part is perceived separately. Then, the overall posture is generated from part of the posture, so as to realize the estimation of athletes' sports posture. The algorithm block diagram is shown in Figure 1. It includes an action segmentation module and pattern recognition module. The purpose of the action segmentation module is to segment the action interval of the original data, so as to extract the data of a single action of athletes, including signal selection, smoothing processing, and segmentation point acquisition.

2.1. Mobile Edge Computing. Based on the machine learning [15–17] methods, a descriptor describing different types of motion is proposed after calculating the moving edge features of the player tracking image time series. The key to using moving edge computing is that the features obtained from a large number of noisy videos are extremely inaccurate. In the process of visual analysis using moving edge calculation, moving edge is considered as the timing displacement information of each pixel in the video frame, which puts forward higher requirements for the accuracy of moving edge calculation [18]. In order to make effective use of the moving edge features of a large number of noisy moving videos, we start with the analysis of the moving edge field and consider the vector field formed by the moving edge vector as movable spatial distribution information. Then, with the help of the motion descriptor of compact expression, the robustness of these features is enhanced. The movement of these images is the result of the relative displacement of the athlete's limbs and trunk. These relative motions are represented in different regions of the tracking image [19]. These local features can not be effectively expressed by global features. At present, we can use the local analysis technology based on grid classification to divide the moving edge field of the adjusted image into nonoverlapping subdomains. Each subfield is called a grid. Through the histogram statistics of each grid, the spatial distribution model of the moving edge field can be realized.

The moving edge feature based on the tracking image can only reflect the motion information of athletes in the image foreground, and the background in the tracking image will affect the moving edge calculation. Therefore, it is necessary to clear the background. Considering the uniform characteristics of the background color of the sports field, it is necessary to adopt the modeling method based on the Gaussian mixture model and use the region growth algorithm for postprocessing to obtain the athletes with global foreground [20].

The light field can be estimated by adjusting the image sequence according to the player with clear background. However, considering the following points, it is necessary to use the difference between adjacent tracking images to calculate the light field. Firstly, the brightness of the athlete's tracking image will be different due to the changes of camera flash and light intensity in the stadium. This difference will lead to incorrect moving edge calculation [21]. Therefore, it is necessary to use image difference calculation to eliminate the influence of brightness change. Secondly, the academic findings of the biological vision system show that human visual cells are more sensitive to the direction and speed of object edge movement. Therefore, the moving edge calculation based on image difference can better reflect the mechanism of the human visual system's response to object motion. Based on the differential image, the horn Schunck algorithm is used to estimate the moving edge field of the player tracking image. The whole calculation process can be formalized as

$$\begin{aligned} \mathrm{EI}_k &= \mathrm{ID}_k - \mathrm{ID}_{k-1}, \\ \mathrm{Mov}_k &= G\left(\mathrm{EI}_k\right) + \delta. \end{aligned} \tag{1}$$

In the equation, EI_k is the tracking image ID_k and ID_{k-1} differential image. Mov_k is the calculated mobile edge field. K is the number of image sequence alignments.

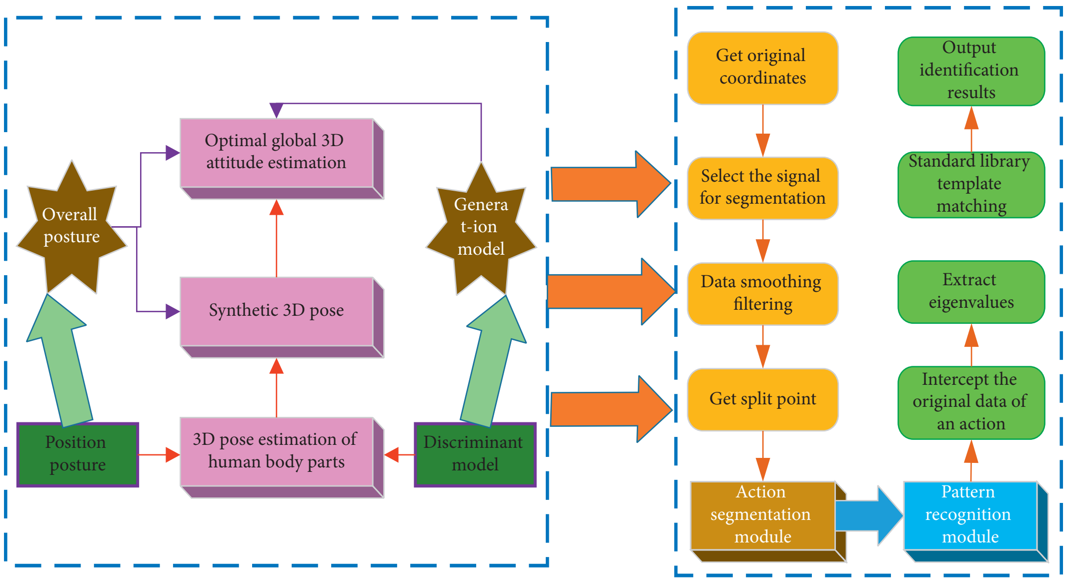

Figure 1: Estimation process of motion attitude.

2.2. *Swing Motion Segmentation*

2.2.1. Action Segmentation Algorithm. The action segmentation algorithm is used to separate the athletes' actions in a period of time and get the starting point and endpoint of each action. The accuracy of the motion segmentation algorithm will directly affect the accuracy of motion recognition and motion counting. The action segmentation algorithm used in this paper can segment continuous complex actions, which is helpful to improve the accuracy of action recognition and counting.

The motion segmentation algorithm needs to select a signal with relatively large signal amplitude and relatively few local peaks and troughs from the nine signals of x-, y-, and z-axis acceleration, angular velocity, and attitude angle. This is conducive to removing local peaks and troughs in later smoothing filtering and improving the accuracy of action segmentation. Since the three-axis attitude angle signal range is -180° to 180°, when the attitude angle exceeds 180°, the signal will suddenly change to -180°, which is easy to misjudge the peak and trough, so only the waveforms of three-axis acceleration. Figure 2 reflects the six signal waveforms of acceleration and angular velocity when athletes continuously perform table tennis forehand action. It can be found that the number of local peaks of the z-axis in an action cycle is relatively small and the amplitude is large, which is more suitable for limited smoothing processing. The arrow in the figure indicates the acceleration signal direction of each axis of the MEMS sensor, and the angular velocity direction of each axis conforms to the spiral law of the right hand of the human body. When the human body performs swing, walking, and running, the arm tends to rotate around the z-axis. After that, the signals of various axes of badminton forehand, walking, running, and other movements are compared. The z-axis angular velocity signal can still reflect good separability. Therefore, this algorithm uses this signal as the segmentation signal.

The diamond represents the peak and trough, and the circle represents the zero point. The smoothed waveform makes it easier to find the signal peak, trough, and zero point by using the program, and the left and right adjacent zeros as the starting point or endpoint are trough and peak, respectively. In order to further reduce the local peaks and troughs caused by action details, this paper adds the minimum threshold Tmin of action interval on the time axis. It is generally considered that the fastest completion time of action of the human body is 0.2 s. All zeros occurring in this time period will be removed; otherwise, the recognition error rate and counting error times will be increased. Therefore, Tmin is selected as 0.2 s. By using the human body detector to detect the position of the player in the badminton swing video segment, the position of the player in the video frame is detected and marked with a rectangular box. Then, only the feature points in the inner region of the rectangular box are detected, and the feature points detected in the region are tracked. In this way, the position information of the trajectory in the video frame not only can be obtained, which reduces the amount of computation of the algorithm, but also excludes the motion trajectory in the other unwanted background, which effectively increases the robustness of the algorithm.

2.2.2. Eigenvalue Extraction. The average resultant acceleration a is the average value of the resultant triaxial acceleration signal of action. The formula is as follows:

$$\overline{\mathrm{Acc}} = \frac{\sum_{i=1}^{N} \mathrm{Acc}_i}{N}. \tag{2}$$

N is the number of sampling points of action. Composite acceleration variance σ_{Acc}^2 is as follows:

$$\sigma_{\mathrm{Acc}}^2 = \frac{\sum_{i=1}^{N} \left(\mathrm{Acc}_i - \overline{\mathrm{Acc}}\right)^2}{N}. \tag{3}$$

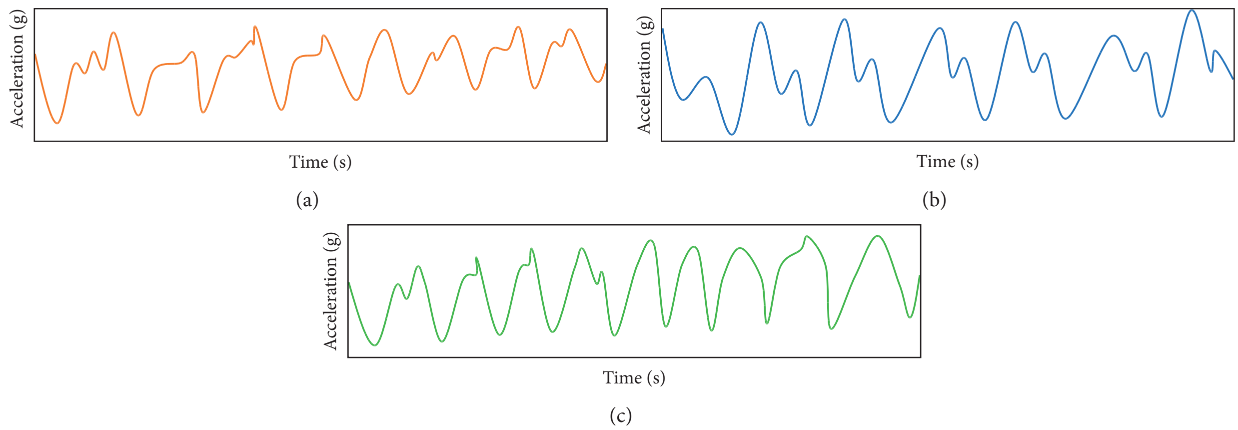

Figure 2: Comparison of acceleration signal waveforms of each axis.

The peak and valley value of synthetic acceleration Acc_{pv} is as follows:

$$\mathrm{Acc}_{pv} = \mathrm{Max}(\mathrm{Acc}) - \mathrm{Min}(\mathrm{Acc}). \tag{4}$$

The average synthetic angular velocity is ω. The average value of the synthesized three-axis angular velocity signal of an action is calculated as follows:

$$\overline{Av} = \frac{\sum_{i=1}^{k} Av}{K}. \tag{5}$$

Composite acceleration variance σ_{Av}^2 is as follows:

$$\sigma_{Av}^2 = \frac{\sum_{i=1}^{N} \left(Av_i - \overline{Av}\right)^2}{N},$$
$$Av_{pv} = \mathrm{Max}(Av) - \mathrm{Min}(Av). \tag{6}$$

The formula is as follows:

$$\mathrm{Cov}(\mathrm{Acc}, Av) = \frac{\sum_{i=1}^{k} \left(\mathrm{Acc}_i - \overline{\mathrm{Acc}}\right)\left(Av_i - \overline{Av}\right)}{(k-1)}. \tag{7}$$

The attitude angle changes ϕ_x, ϕ_y, and ϕ_z of x, y, and z axes are expressed by the following equations, respectively.

$$\phi_x = \sum_{i=2}^{k} \left|\omega_{x,i} - \omega_{x,i-1}\right|,$$
$$\phi_y = \sum_{i=2}^{k} \left|\omega_{y,i} - \omega_{y,i-1}\right|, \tag{8}$$
$$\phi_z = \sum_{i=2}^{k} \left|\omega_{z,i} - \omega_{z,i-1}\right|.$$

2.3. Recognition of Swing Movement. As described above, the movement of the athlete in the adjustment image is caused by the relative displacement in his body, and these movements exist in the corresponding image area. For different gestures, the spatial distribution of the moving edge field is different. The whole process of swing recognition includes data acquisition, window interception, feature extraction and selection, and recognition algorithm research. In Figure 3, the moving edge vector of the image of the up swing racket is densely distributed in the upper part of the image. In the normal image of the left swing of the racket, the moving edge field on the left is more concentrated than that on the right. In contrast, in the image of the right swing racket, the right side is denser than the left side. The usual action recognition methods only use the distribution characteristics and characterize them based on the idea of local analysis. In this paper, an effective region division method is proposed, which is called mesh division.

The moving edge field after smoothing and denoising is divided into nonintersecting grid regions in the vertical and horizontal directions of the adjusted image. Theoretically, meshing can be constructed in any spatial form. Specifically, the number of vertical and horizontal grids is random. However, considering the adjustment of the player's body structure and computational complexity in the image, we use $3 * 3$ grid segmentation. Too simple partition model cannot give a complete description of the spatial distribution of moving edges. However, too complex partitions such as $5 * 5$ and $7 * 7$ will reduce the grid area, so it is estimated that the histogram of moving edges will become sparse. A dense trajectory algorithm can be selected as the basic algorithm for badminton swing recognition, and then, optimization measures are proposed on the basis of this algorithm, so that the algorithm can recognize badminton swing more effectively.

Its main principle is to identify the pixels with an obvious color change or brightness change in the digital image. The significant change of these pixels often represents the important change of this part of the attributes of the image, including discontinuity in depth, discontinuity in direction, and discontinuity in brightness. Based on the kernel density estimation of color layout and the grid histogram of direction gradient, a moving edge histogram based on grid division is developed as the motion descriptor of player swing. For an optical vector with coordinate P in a given moving edge field, its horizontal and vertical components are $H_x(r)$ and $H_y(r)$, respectively. Then, use equation (2) to define the amplitude $N(r)$ and the direction angle $\delta(r)$:

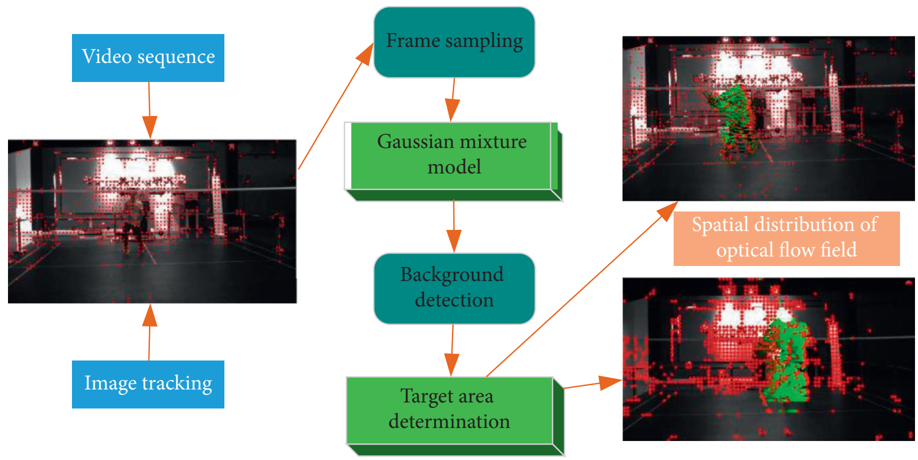

Figure 3: Distribution of movement edge field of athletes.

$$N(r) = \sqrt{H_x^2(r) + H_y^2(r)},$$
$$\delta(r) = \arctan\left[\frac{H_x(r)}{H_y(r)}\right]. \tag{9}$$

The main idea of grid division based on moving edge histogram is that for each grid region, the moving edge vector of any coordinate r is the angle after $N(r)$ weighted quantization $\delta(r)$ of the magnitude. The quantization weighting strategy not only considers its own amplitude $N(r)$ but also uses the kernel density estimation method to consider the distribution information of adjacent moving edge vectors.

Using the existing sports posture database C, the sports posture sample set D can be obtained through classification. For the new athlete posture image, the athlete's posture can be determined only by looking for the sample with the maximum probability of $p(y|z)$. X represents the posture state variable of a specific part, and Z represents the posture state variable of the athlete's posture image.

First, we take $p(y|z)$ as the edge distribution of motion attitude sample set D; then,

$$p(y|z) = \sum_i p(y|z, D)p(D), \tag{10}$$

where $p(y|z, D)$ is used to represent the position posture state variable x; that is, it conforms to the athlete's observed posture state variable Z. At the same time, it belongs to the probability of motion attitude sample library D.

Assuming that the position attitude state variable x and the motion attitude sample library D are independent of each other, there are

$$p(z|y, D) = \frac{p(z|y)p(z|D)}{p(z)}. \tag{11}$$

Then, the equation can be changed to

$$p(y|z) = p(z|y)\sum_i p(z|\mathrm{D})p(y, D)p(D). \tag{12}$$

It is assumed that all attitude samples in the attitude sample library are evenly distributed, and the probability of p (D) is uniform. Then, the posterior probability can be simplified as

$$p(y|z) = p(z|y)\sum_i p(z|\mathrm{D})p(y, D). \tag{13}$$

After classification, the set of samples in category D can be reasonably regarded as Gaussian distribution; that is, it meets the following requirements:

$$y|D \sim N(\mu, Z). \tag{14}$$

μ and Z are the probability mean and covariance of the sample in the motion attitude sample set D. Then, the probability of occurrence of posture state variables on the athlete's posture image is

$$p(z|D) = \int p(z|y)p(y|D). \tag{15}$$

For the Monte Carlo approximate calculation of equation (5), firstly, the probability p $(x|c)$ needs to be sampled and calculated. Then, the confidence $p(z|y)$ of each sampling point is calculated. Finally, the weighted sum of the confidence of all sampling points is obtained.

Then, according to the above equation (4), under the condition of giving the athlete's posture state variable z, the posterior probability $p(y|z)$ can be calculated for each sports posture example y in the sports posture database D. Through this value, we can judge the similarity between the athlete's current posture and the sample posture in the database, so as to estimate the athlete's posture. In order to put forward the shortcomings of the action to be analyzed in the execution process, we need to get the difference between it and the standard action.

3. Posture Evaluation of Badminton Players

In the process of badminton players' movement, there are high requirements for the standard degree of their own actions, but in training, they always rely on the coach's correction of badminton players' posture, and there is no more accurate evaluation system. After analysis, the human posture evaluation system designs an algorithm: take a group of bone point coordinates of badminton players in the camera coordinate system in a single frame image as input, compare it with the badminton players' standard posture library from the same perspective, and then calculate the matching standard posture and cumulative error. The cumulative error reflects the similarity with the matched standard attitude. The lower the cumulative error, the higher the similarity.

3.1. Human Posture Evaluation Algorithm

3.1.1. Algorithm Flow. The overall flow of the human posture evaluation algorithm is shown in Figure 4.

The specific process is as follows:

(1) Coordinate conversion is performed on the coordinates of human bone points conforming to the 13 point human posture model, the image pixel coordinate system is converted to the rectangular coordinate system with point 0 as the origin, and the vectors from the coordinates of each human bone point to point 0 and the included angle between the vectors and the bone points formed in the positive direction of the x-axis of the rectangular coordinate system are calculated, respectively.

(2) Set the priority of each bone point, take one bone point in sequence according to the priority, calculate the cumulative difference with the corresponding bone points of all pose models in the candidate pose set, and output the cumulative difference. After all bone points of the pose model to be measured are calculated, enter step (3). Wherein, the cumulative difference is the absolute value of the difference of the included angle of the bone points in step (1), and the candidate posture set is initially a preset human posture standard library.

(3) Calculate the cumulative error, find the attitude model with the smallest cumulative error in the candidate attitude set, and output the serial number of the attitude model and the cumulative error. The cumulative error is the sum of the cumulative differences of each bone point in the attitude model of the attitude model to be measured in a candidate attitude set.

3.1.2. Algorithm Analysis. At present, the mainstream human posture evaluation algorithms are human posture evaluation in the world coordinate system. The conversion from camera coordinate system (image pixel coordinate system) to world coordinate system requires a depth camera. At the same time, there is an origin (0,0,0) in the conversion process. By comparing the vector set of human postures in the world coordinate system, we can achieve real-time tracking and evaluation of human posture.

This algorithm is different from most current human pose evaluation algorithms. Although it is more comprehensive to evaluate human pose in three-dimensional space, the cost of methods such as depth camera and binocular vision to supplement the missing information in the conversion process is too high. Therefore, this algorithm matches the human posture with the standard posture library under the image pixel coordinate system, so as to obtain the evaluation results, and makes the standard human posture library (forehand, backhand, and jump ball) in badminton for testing.

The evaluation part of the human pose evaluation algorithm has three steps: (1) coordinate transformation of the input bone point coordinates, (2) matching with the standard attitude library, and (3) matching result processing.

In the image pixel coordinate system, the change of human posture coordinate set is not only affected by the position of badminton players on the badminton court (such as front and rear half-court, left and right half-court) but also affected by the camera model, so it can not be directly matched with the standard posture. If we want to match the human posture coordinate set, the above two problems must be solved. The idea of this algorithm is to transform the input coordinates. The transformation steps are mainly divided into two steps, as shown in Figure 5.

The transformation step (a) is carried out because the athletes' different positions on the badminton court will lead to problems in matching with the standard posture. Even if a certain posture appears in different positions on the badminton court, it will show different coordinates in the camera perspective. Therefore, this algorithm puts forward an idea: convert the input coordinate system to the coordinate system composed of the athlete's own human body, so that the positions of the other 12 bone points are determined relative to the neck point. Regardless of the standard posture or the input athlete posture, the neck point is the origin, which can eliminate the problems caused by different positions.

The reason for performing the transformation step (b) is that there are differences between individual body shapes, which will lead to uncertain matching results even if each individual makes the same posture. Therefore, based on the "cosine similarity," the (b) transformation step is proposed: transform the image pixel coordinate system into a rectangular coordinate system with the neck point as the origin, and solve the included angle between the vector formed by the other points and the origin and the positive direction of the x-axis, in order to eliminate the uncertainty caused by this individual difference.

3.2. Matching Human Posture with Standard Library. In the human posture evaluation system, the human standard posture database is also an important index. If the human body standard posture itself is not standardized, the accuracy of human body posture evaluation cannot be guaranteed. Due to the complexity of modeling and the continuous improvement of the effect of deep learning, human posture estimation has gradually focused on deep

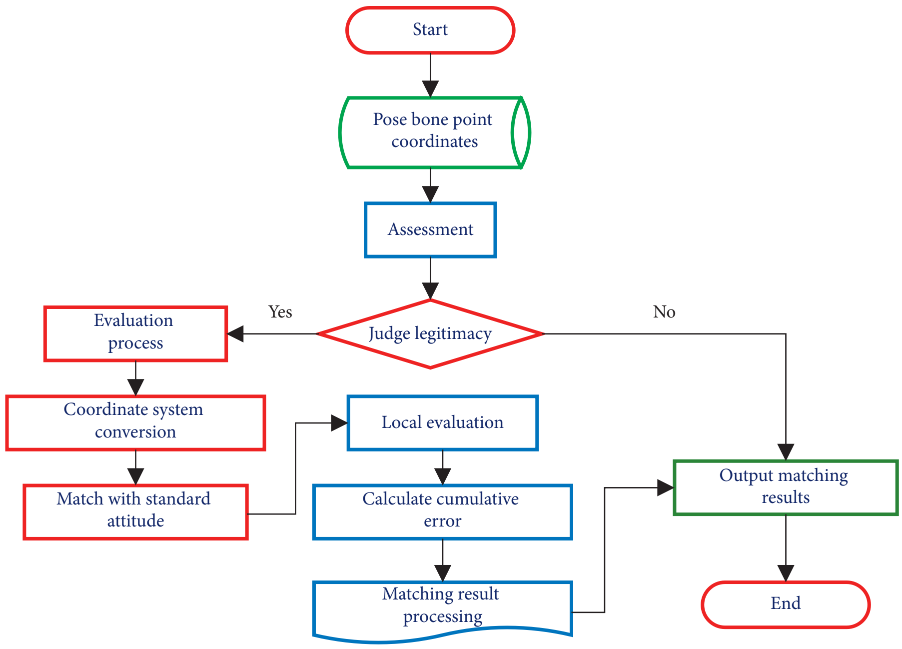

Figure 4: Human posture evaluation algorithm flow.

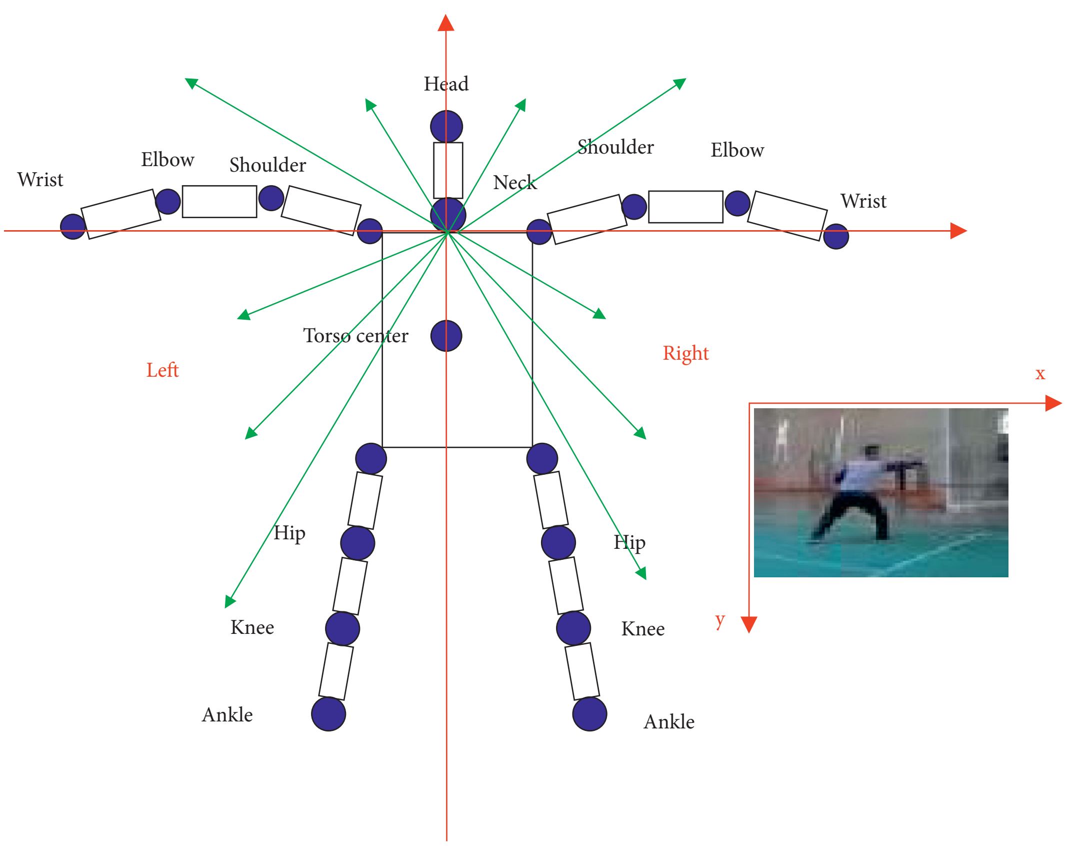

Figure 5: Bone point coordinate system.

learning, but estimation speed and ReLU optimization are still a new challenge. Therefore, in order to show the effect, this algorithm selects three actions: forehand pick, backhand draw, and jump ball, so that an athlete can make a standard posture first and then calculate the parameters of the standard posture of the human body through the process shown in Figure 6. Calculate the similarity between the action and the standard action of this kind of action, and

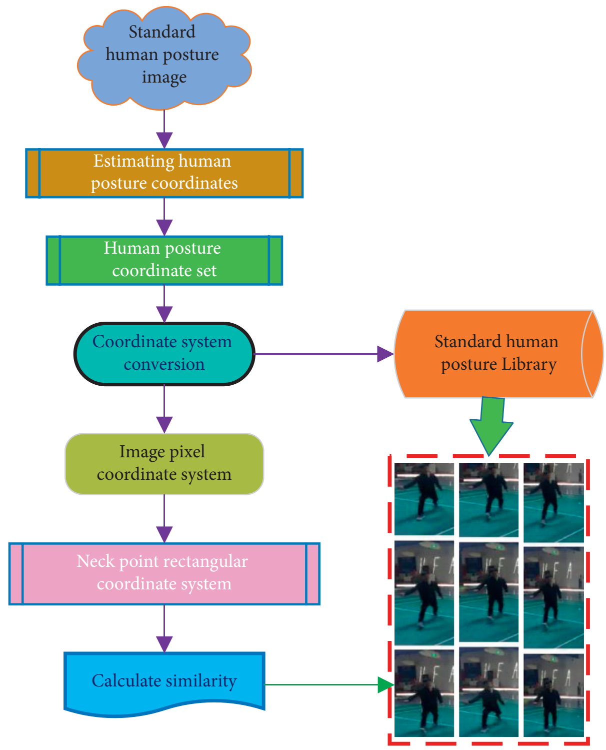

FIGURE 6: Production process of standard human posture library.

then use the scoring formula to calculate the score of the action through the similarity.

After the coordinate transformation of the rest points in the human posture model, the serial number is readjusted. The right upper limb area contains three bone points: right shoulder, right elbow, and right wrist. The adjusted coordinate numbers are 0, 1, and 2. The left region of the upper limb contains three bone points: left shoulder, left elbow, and left wrist. The adjusted coordinate numbers are 3, 4, and 5. The right area of the lower limb includes three bone points: right hip, right knee, and right ankle. The adjusted coordinate numbers are 6, 7, and 8; The left area of the lower limb contains three bone points: left hip, left knee, and left ankle. The adjusted coordinate numbers are 9, 10, and 11.

The overall matching process is divided into 9 small stages, matching 0, 1, 2, 6, 7, 8, 9, 10, and 11 areas, respectively. The of each small area is to take the corresponding angle between the attitude to be evaluated and the candidate standard pose in the previous stage and calculate the absolute value of the difference between them, which is later called cumulative error. If the cumulative error is less than or equal to the allowable error of this stage, the standard pose of the human body conforms to the evaluation of this stage, and the standard pose is put into the candidate standard pose set of this stage.

There are two possible evaluation results in this process: (1) if the angle of the pose to be evaluated in this stage is the loss angle due to the absence of the bone point in the input), the candidate standard pose set in this stage is the candidate standard pose set in the previous stage, that is, skip this stage. (2) After all matching is completed, if there is no candidate standard pose set in this stage, the comparison output result is directly ended. The output results include all the standard poses matched, the stage at the end of matching, and the loss caused by the accumulation of accumulated errors in the matching process.

After the human posture evaluation algorithm, there are two output results: one is the most appropriate standard human posture sequence number, and the other is the similarity with the matched standard human posture, expressed by loss. The matching results obtained in the human posture evaluation algorithm also need to be processed.

If "−1," "0", and "1" appear, this indicates that the comparison of the left area of the upper limb is not completed, and "matching failed" is output. Because the key point of a badminton player's posture matching is the left area of the upper limb, it represents the badminton player's racket holding posture, which is the key area to judge whether the badminton action is standard or not. If "matching failure" occurs, it indicates that the posture of the athlete in the frame image does not conform to any posture in the standard library.

If other information appears, the matching result has appeared. The higher the sequence number, the better the matching result. The loss reflects the similarity between the standard posture meeting the matching conditions and the human posture to be matched at the same stage. The lower the loss, the higher the similarity. How to introduce this feedback into the process of human posture evaluation is still the focus of follow-up work, and it is also a breakthrough for human posture evaluation algorithms to improve the accuracy of evaluation.

How to introduce this feedback into the process of human posture evaluation is still the focus of follow-up work, and it is also a breakthrough for human posture evaluation algorithms to improve the accuracy of evaluation. In the follow-up research, we not only need to get the similarity between the action to be analyzed and the standard action but also give the differences between them, so as to provide the basis for the subsequent correction opinions of the action to be analyzed.

4. Experimental Results and Analysis

We used badminton competitions from radio and television programs and the London Olympic Games. Video is stored in MPEG-2 compressed format, and the size of the video frame is $352 * 288$. The types of different swings in these competitions are marked in manual mode. The real value is created in the ground truth, as listed in Table 1 and Figure 7, including the game name, player, video time length, and the number of three swings.

In order to quantitatively evaluate the algorithm, three evaluation indexes are defined in this paper. Firstly, recall rate (R) and accuracy rate (P) are defined to determine the recognition ability of each swing.

4.1. Action Recognition Results. For the badminton video data shown in Table 1, a classifier is trained to judge the players' actions. All data use the three times cross-validation strategy to form the training set and test set, that is, 2/3 of the data are used as training samples, and the rest are test samples. After three iterative tests, the average of the three evaluation data is considered as the final result. Table 2 shows the experimental results of the algorithm. The experimental comparison results of action recognition are shown in Figure 8.

It can be seen from Table 2 that, for badminton competition, the methods proposed in this paper have good recognition accuracy, which can reach 87.6%. In the test video, the moving image has 30~40 pixels. Due to factors such as low-quality video and camera movement, the swing action is not obvious in every detail. The above research results confirm that the proposed motion descriptor and recognition strategy are very effective. In the experiment, the recognition error of swing movement occurs because high-level athletes will use some unconventional swing techniques to hit a difficult return ball in the game. The optical flow field distribution of these abnormal swing movements is different from the normal situation, so the moving edge histogram based on grid division cannot accurately describe these movements.

4.2. Attitude Perception Analysis. While evaluating the motion recognition method based on motion analysis, the effectiveness of the method based on motion pose feature analysis and the recognition method in this paper is compared. The method based on motion posture feature analysis is to track the athlete's action trajectory to obtain the target area. The contour of athletes' action posture is obtained by processing the background, and the action contour information is mapped into a feature space by Karttunen Loeve (KL) transform. Then, the eigenvalues are arranged in descending order, and the eigenvector of the first m maximum constitutes the apparent descriptor of action and gesture. Finally, the nearest neighbor classifier is used to recognize the action sequence according to these descriptors. As in the above experiments, three cross-validation strategies are applied to separate all data into the training set and test set. In the experiment, the structure of the action descriptor is simplified by modifying and selecting the percentage of the sorted apparent vector. The data set used here achieves the best accuracy when the first 80% of the view vectors are selected. The evaluation results based on the action attitude feature analysis method are shown in Table 3. The effect comparison is shown in Figure 9.

It can be seen from Table 3 that the method proposed in this paper is better than the feature analysis method. This is because this method cannot effectively distinguish the changes of camera angle or athlete's working direction in sports video, so the descriptor based on action posture contour reconstruction does not have excellent classification

Table 1: Experimental data of motion recognition.

Game video clip	Up swing times	Left swing times	Right swing times
Olympic games	52	102	147
Masters	251	398	289
Sudirman cup	218	368	378
Open tournament	239	147	191
Total	760	1015	1005

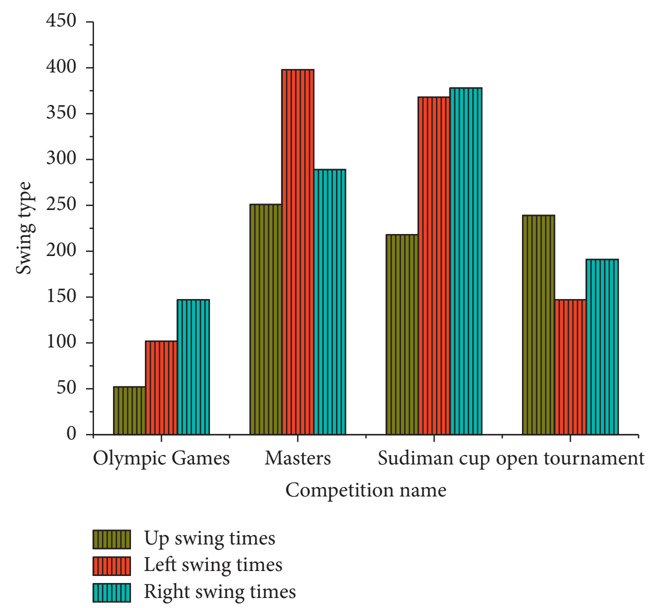

Figure 7: Experimental data display.

Table 2: Experimental results of motion recognition.

Action classification	Action times	Recall rate (%)	Accuracy rate (%)	Accuracy (%)
Up swing	267	88.7	86.5	
Left swing	148	86.6	92.4	89.2
Right swing	181	90.5	93.8	
Average	596	88.5	89.9	89.2

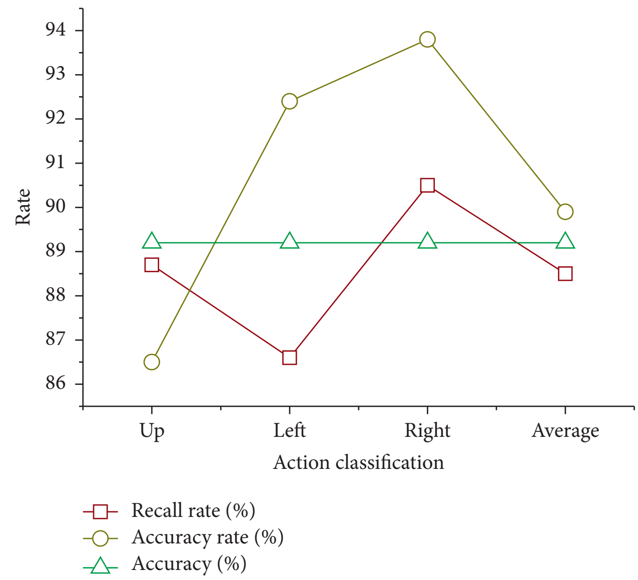

Figure 8: Experimental comparison of motion recognition.

Table 3: Experimental results based on feature analysis.

Action classification	Action times	Recall rate (%)	Accuracy rate (%)	Accuracy (%)
Up swing	267	58.4	63.4	
Left swing	148	65.1	76.2	64.35
Right swing	181	58.7	67.8	
Average	596	60.7	68	64.35

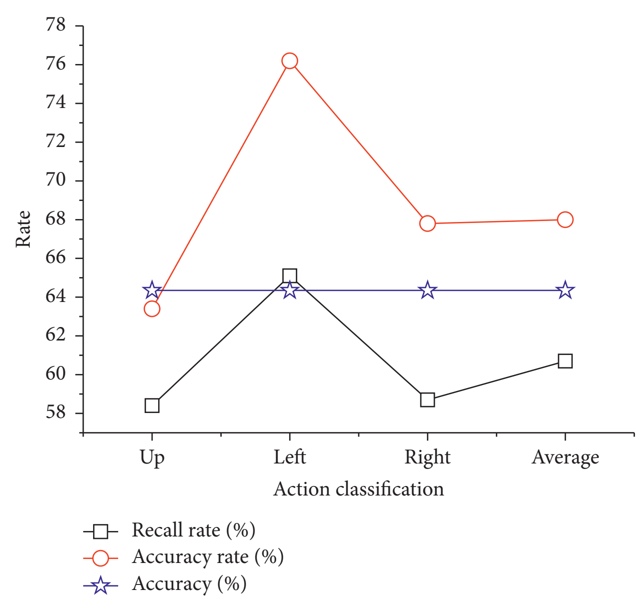

Figure 9: Comparison of experimental results.

Table 4: Record of video frames to be measured and actually measured.

Video name	Number of frames to be measured	Measured frames	Detection rate
Video 1	46	32	0.6956
Video 2	45	43	0.9555
Video 3	132	88	0.6667
Video 4	65	43	0.6615
Video 5	34	26	0.7647
Video 6	51	45	0.8823

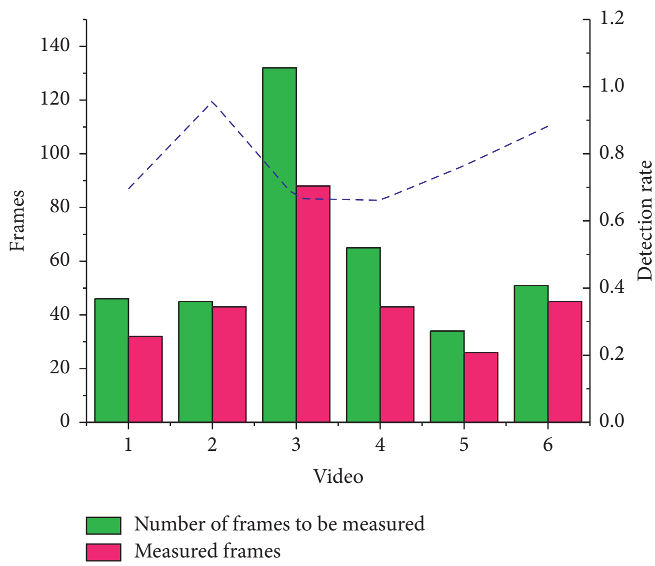

Figure 10: Comparison between the number of frames to be measured and the number of frames actually measured in the video.

robustness. Through comparison, it can be concluded that the motion descriptor in this paper is much better than other motion descriptors in robustness.

Six videos are used for the human posture evaluation module to count the number of frames of posture that should be detected in each video, which is called “frames to be measured.” Counting the number of frames of attitude actually detected in each video is called “measured frames.” The data comparison is shown in Table 4 and the effect comparison is shown in Figure 10.

5. Conclusion

In badminton competitions, athletes’ attitude perception information can become an important semantic clue to understand the competition process, discover technical details, and extract highlights. Therefore, this paper studies badminton athletes’ attitude perception based on moving edge computing. Taking the badminton game video as the research object, the badminton player’s swing action in the time-series image is tracked and recognized. The segmented three-dimensional pose estimation method is adopted to realize the three-dimensional perception of the badminton player’s pose. The action segmentation algorithm is used to determine the starting point and endpoint of each action, and the counting function of various actions is realized. A motion descriptor based on edge calculation is proposed, and the audio keyword strategy is used to find the player’s swing image. Finally, a group of bone point coordinates of badminton players in the camera coordinate system in a single frame image are used as input. Compared with the standard posture library of badminton players from the same perspective, the matching standard posture and cumulative error are calculated. In the future, we can use the current popular big data and cloud computing-related technologies to build a cloud platform for big data analysis, conduct data mining and data analysis on a large number of players’ competition and training data, and analyze the technical advantages and weaknesses of various athletes, so as to improve the technical level of athletes faster.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

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Research Article

Remote Sensing Image Semantic Segmentation Algorithm Based on Improved ENet Network

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A remote sensing image semantic segmentation algorithm based on improved ENet network is proposed to improve the accuracy of segmentation. First, dilated convolution and decomposition convolution are introduced in the coding stage. They are used in conjunction with ordinary convolution to increase the receptive field of the model. Each convolution output contains a larger range of image information. Second, in the decoding stage, the image information of different scales is obtained through the upsampling operation and then through the compression, excitation, and reweighting operations of the Squeeze and Excitation (SE) module. The weight of each feature channel is recalibrated to improve the accuracy of the network. Finally, the Softmax activation function and the Argmax function are used to obtain the final segmentation result. Experiments show that our algorithm can significantly improve the accuracy of remote sensing image semantic segmentation.

1. Introduction

Image segmentation technology divides the image into different types of uniform areas according to the internal characteristics of the image. It is required that the dividing edge between regions must be accurately delineated; and the internal features of the segmented objects have consistency or similarity. Each area belongs to the same category, and different areas belong to different categories [1]. Its purpose is not only to simplify the information of the image but also to make the image easier to understand and analyze [2–4]. Remote sensing image segmentation technology aims to classify remote sensing images at the pixel level based on actual semantic information. It is divided into a series of areas with landmarks such as roads, farmland, villages, and industrial areas [5]. In recent years, with the advancement of high-resolution earth observation technology, image segmentation has been carried out through data obtained from remote sensing satellites. It is the processing basis for the application research of urban planning, disaster monitoring, target recognition, and so forth [6, 7]. However, the rapid increase in the amount of remote sensing data also brings about many challenges to the segmentation of optical remote sensing images. For example, an increase in spatial resolution brings about higher complexity of ground objects (more shadows and backgrounds). The phenomena of the same substance with different spectrum and foreign substance with the same spectrum are brought about by the drastic change of spectral information. There are huge amounts of data to be processed and features with variable scales to be extracted [8–10].

Deep convolutional neural networks have become the mainstream method to solve image semantic segmentation. The best fitting model is obtained by training the network with a large amount of ground truth (GT) [11]. Existing methods build complex networks by stacking a large number of convolutional layers. Although the recognition accuracy is improved, the amount of calculation is too large [12, 13]. The SE module can increase the influence of useful features in the network. The proportion of useless features is weakened to improve network performance. Through the combination with the ENet network, the accuracy of the remote sensing image semantic segmentation network can be further improved. Therefore, in order to improve the accuracy and speed at the same time, this paper has made improvements based on the ENet network. The specific research content is as follows:

(1) In the encoder, dilated convolution, decomposition convolution, and ordinary convolution are used in an interleaved manner, ensuring the size of the feature map while increasing the receptive field. This makes each convolution output more image information.

(2) In the decoder, the weight of the characteristic channel is adjusted through the SE module. The accuracy of the remote sensing image semantic segmentation network is improved.

(3) The original image size is restored by linear interpolation. Softmax activation function and Argmax function are used to get the final semantic segmentation result of remote sensing image.

2. Related Works

With the development of deep learning, researchers have found that deep neural networks can extract deep features useful for image segmentation [14–16]. At present, the common technical methods of image semantic segmentation can be summarized into two categories. The first category is the traditional image semantic segmentation method. Image segmentation is mainly performed by extracting artificial features as visual information. Some examples are image semantic segmentation method based on threshold, image semantic segmentation method based on edge detection, image semantic segmentation method based on region, image semantic segmentation method based on graph theory, and so forth [17–19]. The features extracted by traditional methods are rough, and the segmentation results lack semantic information. The complexity of the algorithm is low, and the performance of the algorithm is poor in complex scenarios. The second type of method is the image semantic segmentation algorithm based on deep convolutional neural network [20]. In the absence of human operations, the image features are extracted by training a convolutional neural network on the target dataset. Convolutional neural networks (CNN) consist of multiple convolutional layers to form a deep network model. The network obtains the final feature representation through layer-by-layer abstraction of the original input data, so as to realize the deep feature extraction of the original data. At present, most of the segmentation methods based on deep features are extended and developed on the basis of CNN. CNN trains the neural network classifier through layer-by-layer feature learning of optical remote sensing images. Classification is performed at the image pixel level to achieve image segmentation. It is generally composed of convolutional layer, pooling layer, and fully connected layer. Through the combination of these multilayer structures, image features are automatically learned and mapped to a new feature space for representation. As a typical data-driven network, CNN needs a lot of training data to get a good segmentation model. Then the model is used to segment the test image.

Reference [21] proposed an attentional SegNet network semantic segmentation algorithm combining SegNet and attention mechanism. The network can segment vegetation, buildings, water bodies, and roads in remote sensing images. Reference [22] proposed a semisupervised semantic segmentation method for high-resolution remote sensing images based on generative adversarial networks. It only needs a small number of labeled samples to obtain a better segmentation effect. Reference [23] proposed a semantic segmentation method that combines dense connections and the idea of a fully convolutional network (DFCN). In order to automatically provide fine-grained semantic segmentation maps, multiscale filters are used to improve DFCN, which increases the diversity of extracted information. Reference [24] adopts the DeepLabV3 architecture with high computational efficiency, adding spatial pyramid pooling and fully connected fusion path layer. Without reducing the resolution of the feature map, the receptive field of feature points is expanded. The improved algorithm enhances the segmentation effect of high-resolution remote sensing images. Reference [25] used the full convolutional network (FCN) semantic segmentation model to achieve pixel-level image semantic segmentation. It replaces the fully connected layer used for classification mapping in the CNN structure with a convolutional layer. Through the deconvolution operation, the obtained feature heat map is upsampled to the original input image size. At the same time, the intermediate pooling layer information is combined to generate the image prediction segmentation map. Reference [26] combined the spectral recognition index of blue-board houses and bare soil. The index of the remote sensing image is blurred to improve the accuracy and recall rate of segmentation. Reference [27] used Conditional Random Field (CRF), which can obtain global context information, as an optimization method, and it is also a common improvement method. First FCN is used to achieve coarse segmentation, and then CRF is used to refine the segmentation results based on the target's multiscale information. Reference [28] proposed a deep convolutional encoder-decoder structure SegNet to identify and segment objects in cities such as streets and vehicles. The idea of block-by-block upsampling is used to restore the image to the original input size. The memory space is saved by retaining only the pooling index value of the encoder structure, and the detailed information of the image is retained, thereby effectively improving the segmentation accuracy. In [29], using the spectral and spatial feature information of remote sensing images, SegNet is used to extract the building coverage areas of rural areas in remote sensing images. The above methods can accurately extract network features of remote sensing images. However, due to the influence of network depth, the accuracy of feature extraction is not high. In addition, the remote sensing image network features obtained by deep learning are not smooth, and further improvement is needed. This paper proposes a remote sensing image semantic segmentation algorithm based on SE module and ENet model. In the encoding stage, different convolution methods are introduced to increase the receptive field of the model. Each convolution output contains a larger range of image information. In the decoding stage, the compression, excitation, and reweighting operations of the SE module are performed. The weight of each feature channel is recalibrated, and the network accuracy is improved.

3. Remote Sensing Image Semantic Segmentation Algorithm Based on Improved ENet Network

ENet network is a lightweight image semantic segmentation network, which can achieve target pixel-level semantic segmentation. This method has the characteristics of few parameters and fast calculation speed. It meets the real-time and accuracy requirements of remote sensing image segmentation [30]. Based on this, this paper proposes a remote sensing image semantic segmentation algorithm based on improved ENet network.

3.1. ENet Network Structure. The ENet network changes the previous encoder-decoder symmetry structure. The convolution operation is reduced in the decoder, which greatly speeds up the processing speed. The ENet network has an initialization operation for the input image, as shown in Figure 1. Its main purpose is to generate feature maps and to fuse the feature maps generated by pooling and convolution operations. The convolution operation has a total of 13 3×3 filters with a sliding step of 2, and a total of 13 feature maps are obtained. Max Pooling is a noncovered 2×2 sliding window, and finally feature fusion is performed.

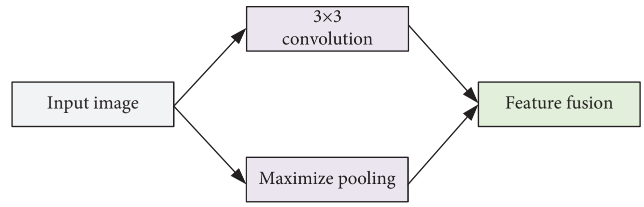

Figure 1: Initialization operation.

In addition, a Bottleneck convolution structure is also used in the ENet network. It is mainly used in the encoder-decoder structure, and the specific structure is shown in Figure 2. Each Bottleneck convolution module contains 3 convolutional layers. From top to bottom in Figure 2 are a 1×1 projection map for reducing dimensionality, a main convolutional layer, and a 1×1 ascending dimension. Normalization and PReLU activation are performed between the convolution layers. The Bottleneck module is not set in stone and will be changed according to specific operations. If it is a downsampled Bottleneck module, the 1×1 projection mapping is replaced by the Max Pooling layer with a kernel size of 2×2 and a step size of 2, and it is filled with 0 to match the size of the feature map. Conv is a 3×3 conventional convolution, expansion convolution, or full convolution, and sometimes 1×5 and 5×1 asymmetric convolutions are used instead. Regularization is used to solve the problem of model overfitting.

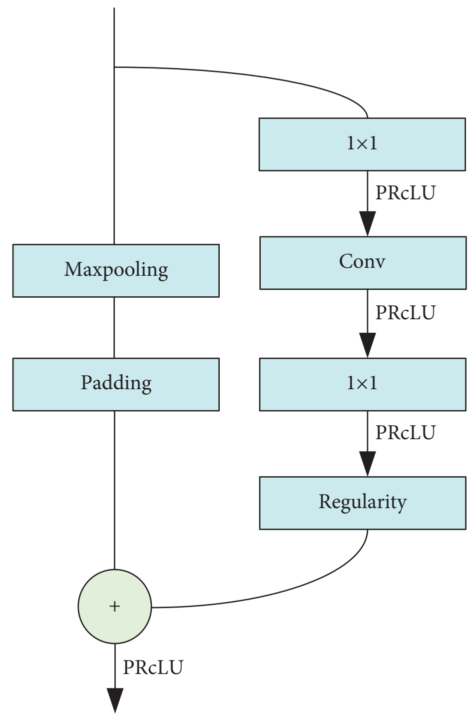

Figure 2: Bottleneck convolution structure.

The overall architecture of the ENet network is shown in Table 1. Between the initialization and the final full convolution, there are also 5 parts. In the first part, there is a downsampled Bottleneck module, followed by four ordinary convolutional Bottleneck modules. In the second part, the first is the Maximum Pooling Bottleneck module, followed by eight different Bottleneck modules in turn: ordinary Bottleneck module, an expanded Bottleneck module with a main convolution expansion rate of 2, an asymmetric Bottleneck module, a Bottleneck module with a main convolution expansion rate of 4, and four Bottleneck modules that are repeated in turn except for the maximum pooling operation. The expansion rate is doubled sequentially; that is, the expansion rate is 2, 4, 8, and 16 in sequence. In the third part, all operations in the second part except the maximum pooling Bottleneck operation are repeated. In the fourth part, there is an upsampled Bottleneck, followed by 2 regular Bottlenecks. The previous operation has extracted enough feature information. Here we need to restore the image resolution to its original size and then output it. Therefore, the fifth part is an upsampled Bottleneck followed by a regular Bottleneck module. The fourth and fifth parts did not use the expanded convolution module. This is because the coding modules of the first three parts have already segmented the image completely. Therefore, there is no need to expand the field of view to extract feature information. The main function of the decoding structure is to restore the resolution of the image. At the same time, the efficiency of network model operation is improved.

3.2. SE Module. The core of the SE module is Squeeze and Excitation. After the convolution operation has obtained features with multiple channels, the SE module can be used

Table 1: Framework of ENet network.

Name	Type	Output size
Initial		$16\times256\times256$
Bottleneck	Downsampling	$64\times128\times128$
$4\times$ Bottleneck 1.x		$64\times128\times128$
Bottleneck 2.0	Downsampling	$128\times64\times64$
Bottleneck 2.1		$128\times64\times64$
Bottleneck 2.2	Dilated 2	$128\times64\times64$
Bottleneck 2.3	Asymmetric 5	$128\times64\times64$
Bottleneck 2.4	Dilated 2	$128\times64\times64$
Bottleneck 2.5		$128\times64\times64$
Bottleneck 2.6	Dilated 2	$128\times64\times64$
Bottleneck 2.7	Asymmetric 5	$128\times64\times64$
Bottleneck 2.8	Dilated 16	$128\times64\times64$
Repeat section 2, without Bottleneck 2.0		
Bottleneck 4.0	Upsampling	$64\times128\times128$
Bottleneck 4.1		$64\times128\times128$
Bottleneck 4.2		$64\times128\times128$
Bottleneck 5.0	Upsampling	$16\times256\times256$
Bottleneck 5.1	Upsampling	$16\times256\times256$
Fullconv		$C\times512\times512$

to recalibrate the weight of each feature channel. The SE module is divided into 3 steps, namely, Squeeze, Excitation, and Reweight. The schematic diagram is shown in Figure 3.

The Squeeze operation uses Global Average Pooling to compress each characteristic channel into a real number. This expands the receptive field to the global scope. The real number is obtained by the following formula:

$$z_k = \frac{1}{W\times S}\sum_{i=1}^{W}\sum_{j=1}^{S}u_k(i,j), \quad k = 1,2,\ldots,N, \tag{1}$$

where u is the feature map obtained after convolution, N is the number of channels of u, and $W\times S$ is the spatial dimension of u.

Next, the Excitation operation captures the compressed real number sequence information. Two fully connected (FC) layers are used to increase the nonlinearity of the module. First, the dimension is reduced through the first full connection layer and then activated through ReLU and then through the second fully connected layer to upgrade, and, finally, through the sigmoid activation function. The whole process is as follows:

$$s = \sigma\left[W_2\delta\left(W_1 z\right)\right], \tag{2}$$

where σ is the sigmoid function, δ is the nonlinear activation function ReLU, and W_1 and W_2 are the parameters of the two FC layers, respectively.

In reweighting, the channel importance coefficient is obtained by multiplying the original feature channel by channel by the excitation operation. The recalibrated features are obtained.

$$\tilde{x}_k = s_k\cdot u_k \quad k = 1,2,\ldots,N. \tag{3}$$

3.3. ENet Network Architecture Integrated with SE Module. The remote sensing image segmentation and extraction process includes three stages: data preprocessing stage, training stage, and testing stage. In the preprocessing stage of remote sensing data, LabelMe is used to manually label and separate remote sensing image features. Training data and test data are generated by cutting the research area. The training data includes the training set and the validation set. K-fold cross-validation is used to realize the automatic division of the training set and the validation set. In the training phase, the preprocessed training samples are input to the improved ENet network with SE structure. The network model architecture is shown in Figure 4. Small batch gradient descent algorithm is used for iterative optimization. When the loss no longer decreases, the iteration task ends. In the test stage, the trained optimal model is applied to the test image for remote sensing image segmentation and extraction.

Figure 4 shows the improved ENet model structure with SE structure proposed in this paper. The model uses an encoder-decoder structure; and the encoder uses conventional convolution and a residual structure with dilated convolution to extract high-level semantic features. After that each layer of convolution is followed by BN and ReLU activation functions. In the decoding stage, image information of different scales is obtained through upsampling operation. Then the weight of each feature channel is recalibrated through the SE module to improve the accuracy of the network. Then the feature map is restored to the original image size through linear interpolation. Finally, the Softmax activation function and the Argmax function are used to obtain the final prediction result, so as to realize the end-to-end remote sensing image segmentation task.

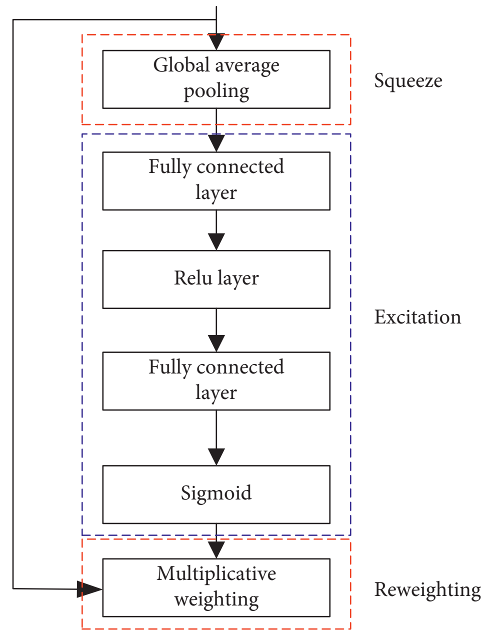

Figure 3: Schematic diagram of SE module.

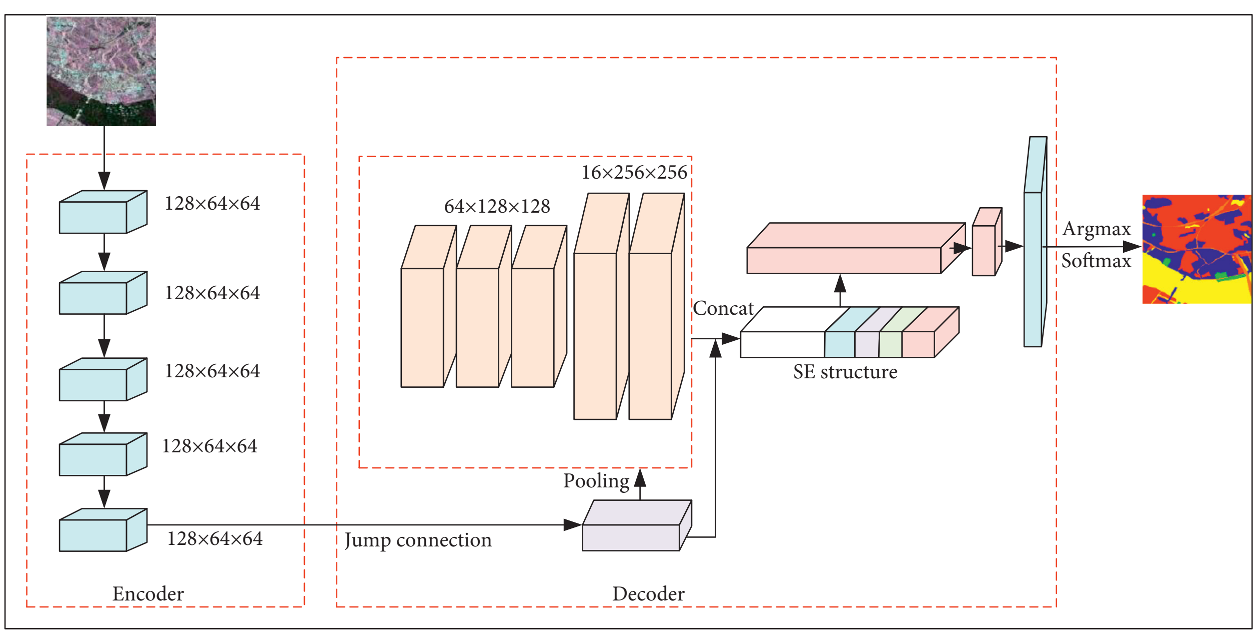

Figure 4: Architecture diagram of improved ENet with SE structure.

4. Experiment

4.1. Experimental Environment and Network Parameters. The computer used in this paper is configured with 16 G memory, i7-8700K CPU, and GTX 1080ti graphics card. The experiment was carried out on TensorFlow. TensorFlow can run on one or more CPU/GPU.

When training the network, in order to enhance the generalization ability of the network, the input image undergoes local response normalization before the first layer of convolution; $\alpha = 0.0001$ and $\beta = 0.75$. The learning rate is set to 0.001 and iterated until the loss function converges. In the training process, the training dataset is randomly shuffled, and then every 5 images are treated as a batch. The objective function of the network uses the cross-entropy loss function; and L2 regularization is added to the last layer of the network to prevent overfitting.

4.2. Evaluation Index. *F*1 score is a measure of classification problems. It is the harmonic mean of precision and recall. The formula is as follows:

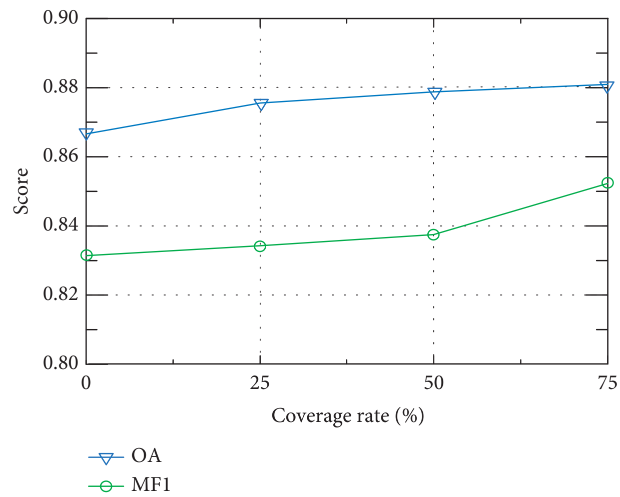

Figure 5: OA and MF1 under different coverage rate.

$$F1 = \frac{2\text{precision} \times \text{recall}}{\text{precision} + \text{recall}},$$

$$\text{precision} = \frac{\text{tp}}{\text{tp} + \text{fp}}, \tag{4}$$

$$\text{recall} = \frac{\text{tp}}{\text{tp} + \text{fn}},$$

where tp is true positive, tn is true negative, fp is false positive, and fn is false negative.

MF1 score (mean $F1$ score) is the average of $F1$ scores, used to evaluate the global standard:

$$\text{MF1} = \frac{\sum_1^n F1_n}{n}, \tag{5}$$

where n is the number of feature types.

Overall accuracy (OA) is the ratio between the correct prediction of the model on all test sets and the total number. It is used to evaluate the global standard:

$$\text{OA} = \frac{\text{tp} + \text{tn}}{\text{tp} + \text{fp} + \text{tn} + \text{fn}}. \tag{6}$$

4.3. Vaihingen Dataset. The Vaihingen dataset was taken in Vaihingen, Germany. The dataset contains 33 remote sensing images of different sizes. Each image is extracted from a larger top-level orthophoto image. It contains 3 channels of IRRG (Infrared, Red, and Green) images, DSM (Digital Surface Model) images, and NDSM (Normalized Digital Surface Model) images. The average size of the images is 2494×2064. The experiment only used IRRG images, not DSM images or NDSM images.

In order to study the effect of the time coverage of the dicing and the crop size on the accuracy of the segmentation, in this paper, experiments with different dicing strategies are carried out on the Vaihingen dataset. Firstly, the crop size is fixed to 512×512. Experiments were performed according to the interblock coverage rates of 0%, 25%, 50%, and 75% (step sizes: 512, 384, 256, and 128, respectively). The experimental results are shown in Figure 5. It can be seen that OA and MF1 score the highest when the coverage rate is 75%.

Table 2 shows the comparison between the proposed algorithm and Semi-GAN [22], DFCNN [23], and DeepLabV3+ [24] on the Vaihingen dataset. Judging from the final score, the algorithm proposed in this article is 2.0% higher than the DNCC algorithm on MF1 and 2.3% higher on OA. From the perspective of different classifications, according to the $F1$ scoring standard, the algorithm in this paper has achieved the first place in the classification of roads, buildings, vegetation, trees, and vehicles. Figure 6 shows the qualitative comparison between this algorithm and the Semi-GAN, DFCNN, and DeepLabV3+ on the Vaihingen dataset. From the challenging high-density car scene in the second row, we can see that the algorithm in this paper divides each car very finely. Other networks even divide the gray cars in the shadows into buildings. From the scenes with more trees and vegetation in the first and third rows, it can be seen that the classification error of the algorithm in this paper is less. Other algorithms often confuse similar features when classifying.

4.4. Potsdam Dataset. The Potsdam dataset was taken in Potsdam, Germany, and it contains IRRG images, IRGB images, DSM images, and NDSM images. The image size is 6000×6000, and the total number of images is 38, of which 14 are used as the test set. In this experiment, 17 images are used as the training set, 5 images are used as the verification set, and 14 images are used as the test set. In the experiment, only IRRG images were used, and two incorrectly labeled images in the training set were deleted.

Table 3 shows the comparison between the proposed algorithm and the Semi-GAN, DFCNN, and DeepLabV3+ on the Potsdam dataset. From the final score, the algorithm proposed in this paper is 1.5% higher than the second DFCNN algorithm on MF1 and 1.1% on OA. From the perspective of different categories, according to the $F1$ scoring standard, the algorithm proposed in this article has

Table 2: Comparison of $F1$, OA, and MF1 in different algorithms of Vaihingen dataset.

Method	F1 (%)					OA (%)	MF1 (%)
	Road	Architecture	Vegetation	Tree	Vehicle		
Semi-GAN	87.8	90.1	75.9	86.5	74.2	84.5	82.9
DFCNN	89.1	90.5	75.2	85.6	75.8	86.1	83.2
DeepLabV3+	85.2	89.4	75.8	82.6	69.2	82.9	80.4
SE-ENet	89.8	91.5	79.3	86.7	78.9	88.4	85.2

Table 3: Comparison of $F1$, OA, and MF1 in different algorithms of Potsdam dataset.

Method	F1 (%)					OA (%)	MF1 (%)
	Road	Architecture	Vegetation	Tree	Vehicle		
Semi-GAN	86.7	90.3	76.1	82.5	75.8	83.5	82.3
DFCNN	87.5	90.8	76.5	84.6	76.1	86.2	83.1
DeepLabV3+	84.6	87.4	75.7	83.9	65.5	91.3	79.4
SE-ENet	88.8	91.4	78.4	84.9	79.7	87.3	84.6

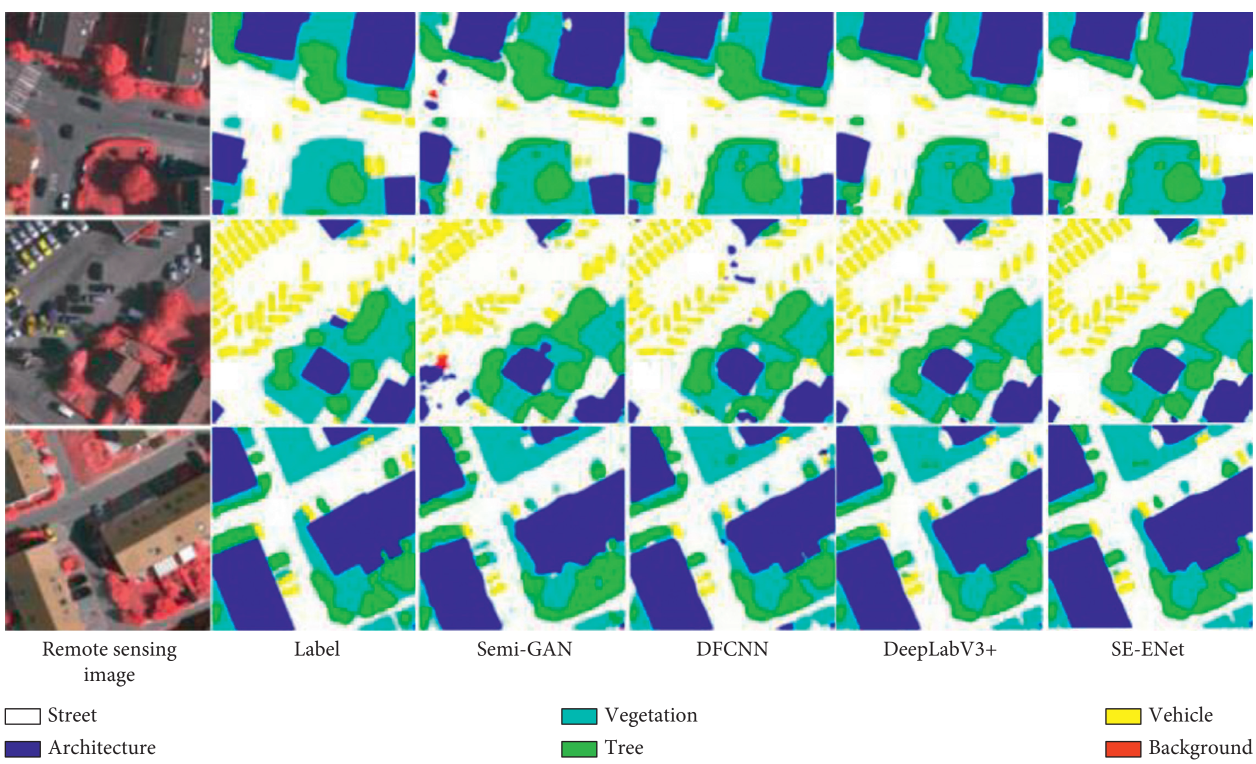

Figure 6: Comparison of different algorithms on Vaihingen dataset.

achieved the first place in all categories. Figure 7 shows the qualitative comparison between the proposed algorithm and other general networks on the Potsdam dataset. From the scene where there are many cars in the second line and a single tree, it can be seen that the division of trees and cars is fine. However, other networks have serious misclassification. It can be seen from the third row that the forest area segmentation is more accurate, and there is less confusion between vegetation and trees. Other networks often misclassify similar features.

4.5. Massachusetts Buildings Dataset. In order to verify the generality of the model, experiments are carried out on the Massachusetts building dataset. The Massachusetts buildings dataset is a large dataset used for building segmentation. The dataset consists of 151 groups of aerial images and corresponding single-channel label images. The size of the images in the data set is 1500 pixels × 1500 pixels. Among them, there are 137 training images, 10 test images, and 4 verification images. The annotated image only contains buildings. Random cropping and data enhancement are used to

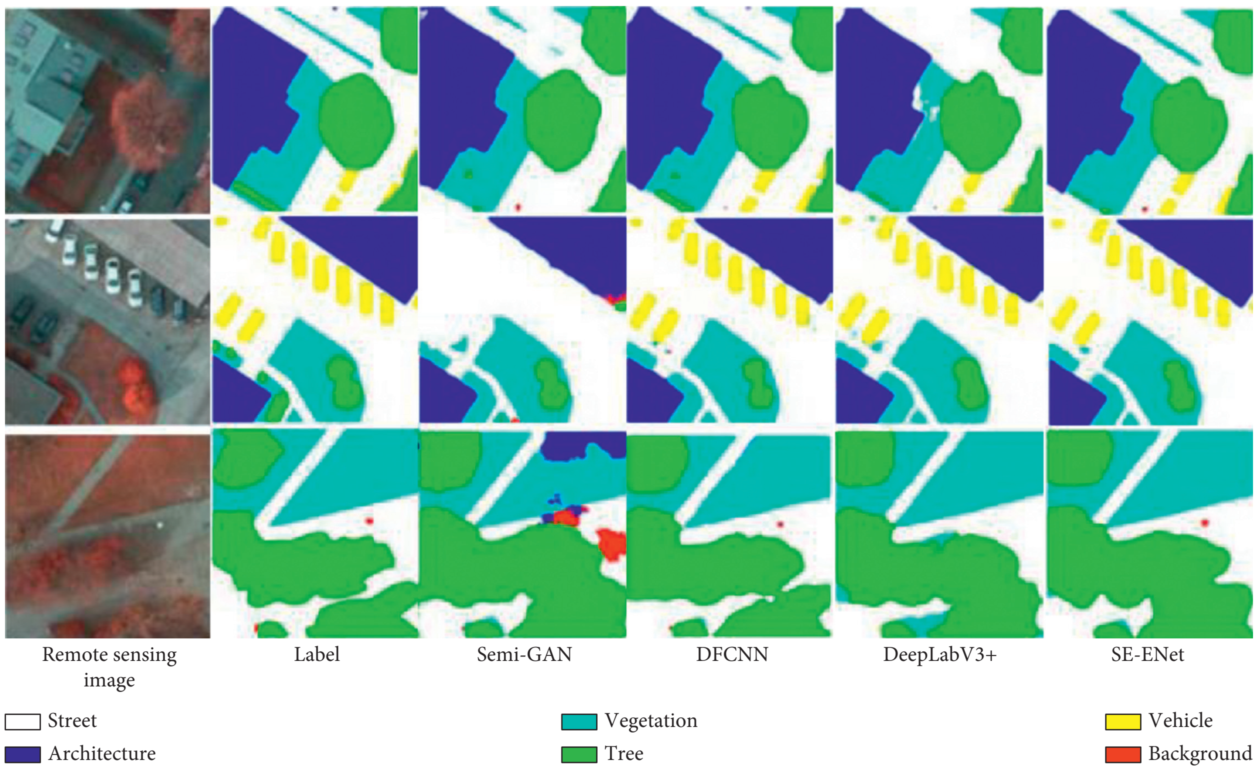

Figure 7: Comparison of different algorithms on Potsdam dataset.

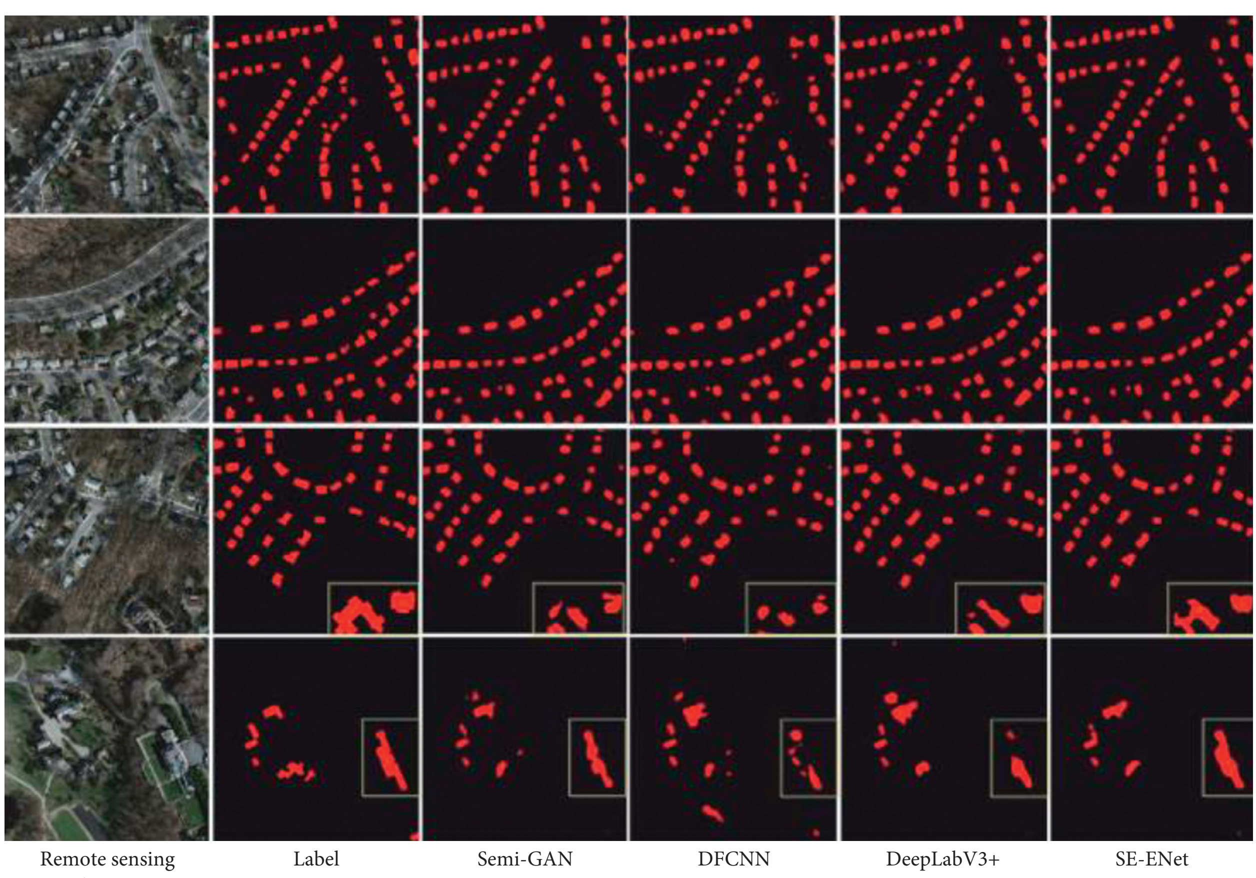

Figure 8: Comparison of different algorithms on Massachusetts building dataset.

Table 4: Massachusetts building image segmentation results.

Method	$F1$ (%)
Semi-GAN	85.4
DFCNN	88.3
DeepLabV3+	88.5
SE-ENet	89.7

generate experimental images with a size of 256 pixels × 256 pixels. The red pixels represent the building area, and the black pixels are the background. The details of the building segmentation experiment are similar to the remote sensing satellite image segmentation experiment. During the training process of segmentation experiment, the number of training images in batch size is 4. The number of training epochs is 10 rounds, and 10,000 batches are trained in each round. There are 3000 test images with a size of 256 pixels × 256 pixels.

The experiment chooses Semi-GAN, DFCNN, and DeepLabV3+ for comparison. Each network is trained 10 times, and the best model is selected for testing. The segmentation result of the network is shown in Figure 8. It can be found from Figure 8 that there is little difference between the networks for the segmentation of small buildings (villas). For the recognition of large buildings (factories, shopping malls), the segmentation results of this algorithm are more complete and refined. In this paper, a segmentation experiment is carried out on 3000 experimental datasets of 256 pixels × 256 pixels. The experimental results are shown in Table 4. It can be seen from Table 4 that SE-ENet achieved an $F1$ value of 89.7%, which is the highest among the comparison algorithms.

5. Conclusion

Through experiments on the TensorFlow platform, this paper proves that the ENet network integrated with the SE module has higher accuracy. It can be better applied to remote sensing image segmentation. Compared with other semantic segmentation algorithms, the image features generated by the proposed method are more complete. Through the introduction of dilated convolution and decomposition convolution and the cross-use of ordinary convolution, the receptive field of the model is increased. Each convolution output contains a larger range of image information. The SE module recalibrates the weight of each characteristic channel to improve the accuracy of the network. Experimental results prove that the proposed algorithm has higher segmentation accuracy. In the following research, we will focus on the segmentation of small and medium targets in remote sensing images to further improve the accuracy and segmentation speed of the model.

Data Availability

The data included in this paper are available without any restriction.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this study.

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