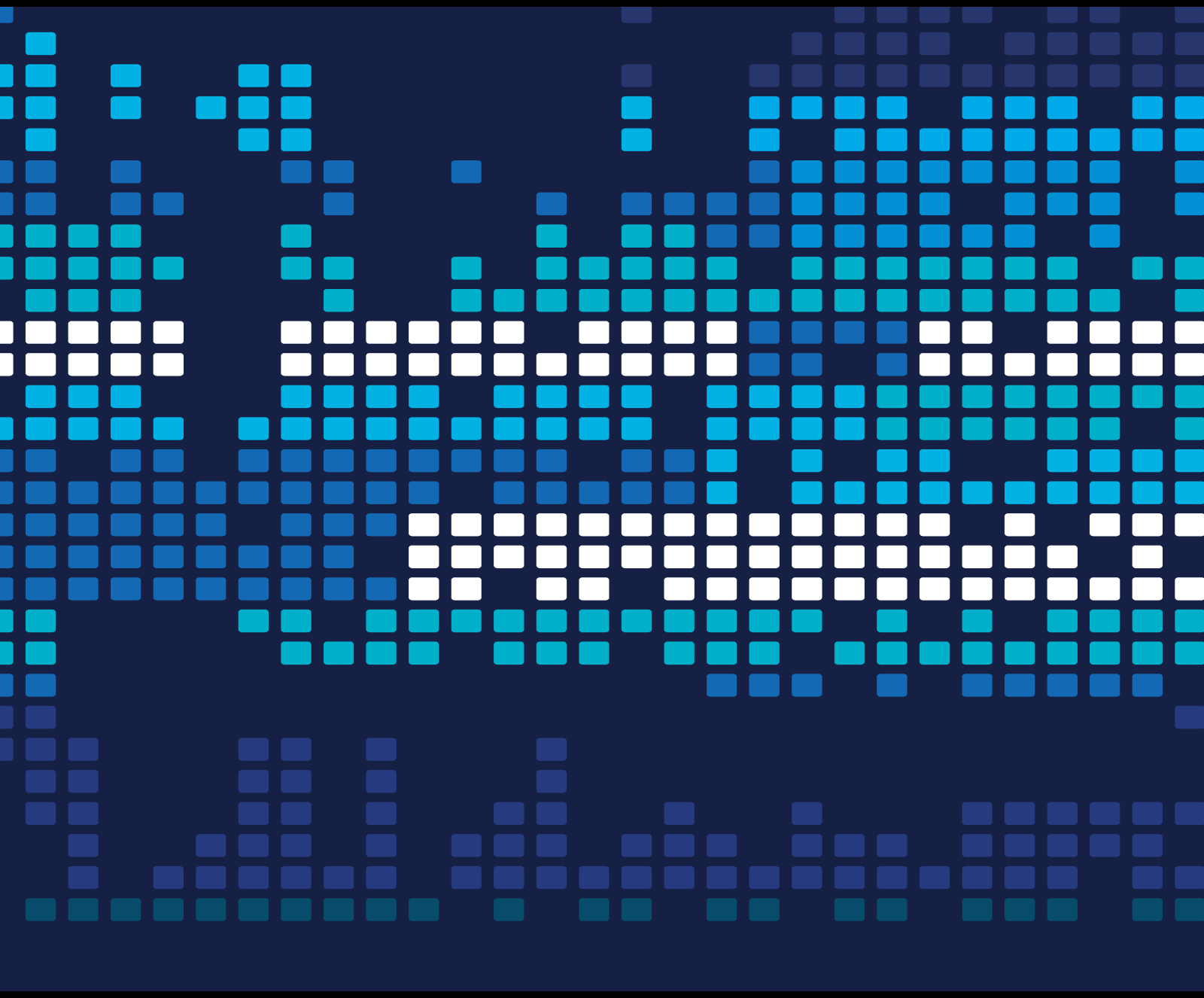
Scientific Programming

Scientific Programming for Smart Internet of Things 2022

Lead Guest Editor: Mian Ahmad Jan
Guest Editors: Houbing Song, Rahim Khan, Abid Yahya, and Muhammad Babar



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Research Article

Application of 2D Images in Visual and Tactile Dimensions of Fiber Art Design

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With people's higher and higher spiritual requirements, fiber art is more common in people's lives. From ordinary fiber materials to handicrafts and daily necessities, there are shadows of fiber art. This paper aims to study the application of two-dimensional images in the visual and tactile dimensions of fiber art design. This paper proposes a three-dimensional simulation of two-dimensional images of art based on deep learning technology to achieve the purpose of convenient display and also analyzes the feature extraction in fiber art. In order to comprehensively compare the performance of the algorithms, this paper compares the performance of four categories: reconstruction speed, number of reconstructed point clouds, diversity of reconstructable categories, and reconstruction stability. The experimental results show that the number of point clouds obtained by the algorithm proposed in this paper far exceeds the other two reconstruction processes, and the average time is 34.4 min. This also shows that such algorithmic processes are more robust to clothing diversity.

1. Introduction

In the increasingly diversified and open modern civilization, the cloth is taken as the research object, and the visual texture and tactile perception characteristics of the cloth are researched with regard to the basic attributes of the fiber material such as color, texture, texture, and pattern. Researchers discuss the expression techniques and expressions of fabrics in fiber art design and creation under modern civilization and the trend of the times, breaking the traditional design thinking mode of fabrics. It is of great significance to study the application of two-dimensional images in fiber art.

For the research on fiber art, this paper has the following two innovations: (1) The first is innovation in perspective. The content of this article is the visual and tactile application of fiber art. Such a perspective pays more attention to the artistic aspect of fiber art, rather than paying too much attention to the material of fiber art itself. (2) The second is innovation in method. The paper proposes a feature extraction algorithm and a three-dimensional reconstruction algorithm for the two-dimensional images of fiber art. Such an algorithm can transform a 2-dimensional image into a 3-dimensional image, thereby more intuitively showing the visual and tactile dimensions of fiber art.

2. Related Work

For today's fiber art, many scholars have conducted in-depth research, especially into the innovation of fiber art. Firth analyzed digital fiber art in combination with digitization technology and analyzed the problem of growing digital photos with users not wanting to delete them [1]. Zhao and Wang introduced the application of FORS in identifying pigments and dyes, analyzing adhesives, and studying preservation outcomes and preservation environments. They discuss detection limits, reproducibility, and signal characterization methods and summarize the future development of FORS in the study of artefacts [2]. Jin and Xia believe that image art analysis and computer-generated art

are frontier application hotspots in the field of visualization. They found that with the gradual deepening of the application of digital technology represented by artificial intelligence in the field of art, the integration of art and digital technology will provide a broader space and prospects for the development of art [3]. Liu analyzed the principle and characteristics of computer image recognition technology, analyzed the existing problems and solutions, and discussed the application of computer intelligent image recognition technology in various fields [4]. Li et al. found that previously presented image matting algorithms might fail to produce favorable results since most of them concentrate on the similarity between the neighboring pixels while neglecting the corresponding spatial relationship. To address this issue, an end-to-end image matting framework through leveraging deep learning mechanism and graph theory is proposed [5]. Wang analyzed the development of traditional hand-woven craftsmanship into modern three-dimensional works, which had a positive impact on people's lives, for example, the application of fiber art in specific products [6]. Zhang introduced new testing methods and typical instruments for fibers and textiles developed at home and abroad, including fiber length, fineness, crimp, heat shrinkage, maturity, irregularity, and fiber structure analysis and testing; yarn fineness, strength, twist, hairiness, unevenness, and defect testing; textile color, gloss, flexural stiffness, drape, wrinkle resistance, heat and moisture transfer, breathability, flame retardancy, color fastness, blending ratio, and UV and radiation protection; and antistatic, antibacterial, anti-mite, anti-moth-eaten, ecological, and safety performance tests. In addition, the study discussed the related technologies of fiber structure analysis, including electron microscope analysis, infrared spectrum analysis technology, X-ray diffraction analysis, and thermal analysis technology. The research specifically mentions that computer image processing technology is widely used in the textile industry and the specific applications mainly include textile fiber detection, textile yarn detection, and textile fabric detection [7]. However, it can also be found from relevant research that many scholars lack corresponding technical support for the study of fiber art, and they are more concerned with analyzing the aesthetic significance of art.

3. Vision and Touch of Fiber Art Design

3.1. Fiber Art in China. The term "fiber art" first appeared in the United States in the 1970s. In China, people are used to calling it "dyeing and weaving art," "weaving art," and "fabric art." In foreign countries, words such as "tapestry" (English) and "textile" (French) are mostly used. With the development of history, the art form with weaving as the main technique has begun a new transformation and extension. Artists began to explore new fiber materials and fabrication techniques, creating new works.

To understand the development history of Chinese fiber art, we have to mention another long-established fiber art form—Chinese carpet. In China, wool fabrics did not appear as early as silk fabrics. The ethnic minorities living in the ancient northwest region were good at using animal wool to spin into woolen yarn and to weave woolen cloth or blankets. As early as the Zhou Dynasty in China, there were records of the manufacture and use of felt. The wool fabrics unearthed at the Wubao site in Hami, Xinjiang, dating back 2,300 years, are already exquisite. There are two kinds of plain weave, twill weave and jacquard fine wool fabrics woven with colored threads. During the Sui and Tang Dynasties, the weaving of carpets had a high level of skill, and tapestries also developed and prospered locally. The kesi tapestries of the Tang Dynasty in China were passed to Japan. The Xinjiang wool fabrics unearthed from the ancient tomb of Zhahong Luke in Qiemo County include printed wool fabrics, painted wool fabrics, wool fragments, silk fabric fragments, and wool fabrics. In the Dunhuang Grottoes, there are a large number of carpet pictures in the murals of the Tang and Song Dynasties, which are exquisite in craftsmanship and highly ornamental and decorative. It can be seen from this that China's fiber art has a long history of development and is very prosperous. In addition to Chinese silk and carpets, Chinese kesi, embroidery, and other techniques also have a long history. They have developed in all dynasties and generations and are also an important part of the history of Chinese fiber art [8, 9].

With the progress of the times, modern fiber art has achieved rapid development in China. In the early 1980s, the textile works of this period were mainly tapestries. They were produced by the traditional flocking process. The design of the works was mainly based on the reproduction of photos and master paintings, and the aim was a realistic and realistic effect. Moreover, most of the fiber art designers in this period were those who used to work in the carpet industry, so they were still mainly flat in form. Until the spring of 1981, American fiber art students had come to the Central Academy of Industrial Fine Arts to study abroad. Through study and exchange, the research and development of Chinese modern fiber art began to internationalize [10, 11].

Under the influence of the artistic trend of the 20th century, fiber art has already belonged to a new expression of modern art form. It has been difficult for traditional titles to accurately cover this art. Whether traditional or modern, the decisive factor in this art is the fiber material. Works made from fibers belong to the category of this art. It is therefore reasonable to call this art "fiber art."

3.2. Visual Affinity. Vision is the most direct way of communicating and perceiving information. People use the eyes as a medium to observe and examine the fabric. This forms the intuitive impression and psychological feeling of the fabric, which is the visual texture of the fabric. The influencing factors of the visual texture effect mainly include the appearance pattern design of the fabric, the structure of the fabric, and the internal texture of the fiber element. Appearance patterns of fabrics refer to the appearance patterns attached to the surface of fabrics by means of printing, hand-painting, spray painting, etc. during fabric processing. Different attachment drawing techniques and patterns of different colors, shapes, shades, thicknesses, and densities bring different psychological feelings to the audience. For

example, "in the 1990s, the patterns attached to the fabrics were mostly printed. Common patterns are repaints of natural features, such as animals, flowers, landscapes, etc. This realistic and natural appearance pattern is vivid under the drawing technique of printing. Its full and rich imitation reproduces the vitality and agility of the natural ecological environment."

The weave structure of the fabric refers to the organization law formed by the interweaving of the warp and weft threads in the woven fabric according to certain rules. As components of the fabric system, the weaving technique, yarn shape, yarn texture, luster, etc. of the fabric will affect the visual artistic effect of the fabric. For example, in plain weave, the warp and weft are alternately woven up and down (as shown in Figure 1). It forms a dense arrangement of warp and weft yarns, and the fabric under the plain weave is a point-like composition surface from a visual perspective. The surface of the fabric is smooth and regular, and the style is stiff. If dark-colored yarns are used, the fabric gloss and visual perception fineness under the plain weave method are not high. Under the light and dark light, the unevenness of the fabric surface will present a three-dimensional sense and spatial hierarchy.

3.3. Tactile Texture. For cloth, texture is the touch of the cloth. The human body surface skin is used as a medium to stroke the cloth, and the mutual contact and friction between the human body surface texture and the cloth surface texture are used. It senses the fibrous elements and tissue structure inside the cloth by tactile nerves. This arouses the intuitive psychological feeling of the toucher on the fabric and forms an intuitive impression of the texture effect of the fabric. It is further deepening the artistic perception of cloth and further rendering the artistic appeal.

The texture of the fabric is an important natural attribute and a unique aesthetic form of the fabric, which constitutes the unique artistic charm of the fabric. Different fabrics have different textures in terms of touch, and the texture effects and psychological feelings brought to the touch are also different. Generally speaking, fabrics with a smooth surface texture and no obvious abrupt texture feel smooth to the touch. For example, the striped texture on the surface of the cloth will give the touch a sense of fluidity and regularity. The cotton fabric is soft and delicate to the touch, and the silk is light and smooth to the touch, which will bring softness and comfort to the touch. They make the toucher feel the natural pleasure of tranquility, peace, and serenity and are usually used for summer cool quilts or intimate clothing designs. Although the fabric with rough surface texture and heavy wool texture is lacking in touch, it can bring warmth and fulfillment to the touch. For example, bumps on the surface will give the toucher a sense of three-dimensionality and irregularity. Under light mapping, there will be obvious spatial hierarchy and directionality. The hemp fabric is light in quality but has a rough surface that can tingle when touched. It has a poor affinity with the skin and is mainly used to design clothing for hot seasons. The cloth mainly made of animal fur has a rough surface texture and touch, but it can give people a warm feeling and spiritual comfort like hugging and soothing pets.

Therefore, the texture of the fabric is not only the internal combination of fiber elements, but also the emotional characteristics of "humanization." When choosing fabrics, modern people not only consider the visual affinity, but also perceive the texture that the fabric gives the touch. They seek suitable fabrics that meet the modern people's pursuit of texture and conform to modern people's psychological emotions.

4. Feature Extraction of Fiber Art Based on Two-Dimensional Images

4.1. Feature Detection and Extraction. The first step in the motion structure recovery process is feature extraction, and the extracted features need to be used in the matching in subsequent steps and inference of depth and camera position. The desired feature extraction algorithm in this paper can be as invariant as possible to scaling and rotation, as well as lighting and camera angles. It maintains the stability and consistency of feature points under different viewing angles. The scale-invariant feature transform matching algorithm [12] is the most widely used and spread feature matching algorithm. It is used in most kinematic structure restoration components.

The SIFT algorithm is used to find key points in different scale spaces, and the scale space of the image can be obtained by Gaussian blurring of the image. This paper defines this process as function $L(x, y, \sigma)$, which can be obtained by convolving the original image $I(x, y)$ with Gaussian filter $G(x, y, \sigma)$, as shown in the following formula:

$$L(x, y, \sigma) = G(x, y, \sigma) \cdot I(x, y). \tag{1}$$

The two-dimensional filtering expression $G(x, y, \sigma)$ is defined as follows:

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-\left(x^2+y^2\right)/2\sigma^2}. \tag{2}$$

The effective detection of stable feature points is to perform extreme point detection on the difference of Gaussian constructed by the adjacent scale-space difference after convolving with the image Gaussian [13]. The spatial factors σ of different scales differ by k times, and the differential pyramid formulas are expressed as follows:

$$D(x, y, \sigma) = [G(x, y, k\sigma) - G(x, y, \sigma)] \cdot I(x, y), \tag{3}$$

$$D(x, y, \sigma) = L(x, y, k\sigma) - L(x, y, \sigma). \tag{4}$$

The composition of the Gaussian pyramid is shown in Figure 2. Pyramid has multiple groups (octave), and each group has multiple layers. The scales of multiple layers in a group are different; that is, parameter σ is different. The scales between the two layers differ by a scaling factor k [14]. If each group contains S layers, there is the relationship of the following formula:

Figure 1: Schematic diagram of plain weave pattern and warp and weft weaving. (a) Plain weave layout. (b) Schematic diagram of weft yarn weaving.

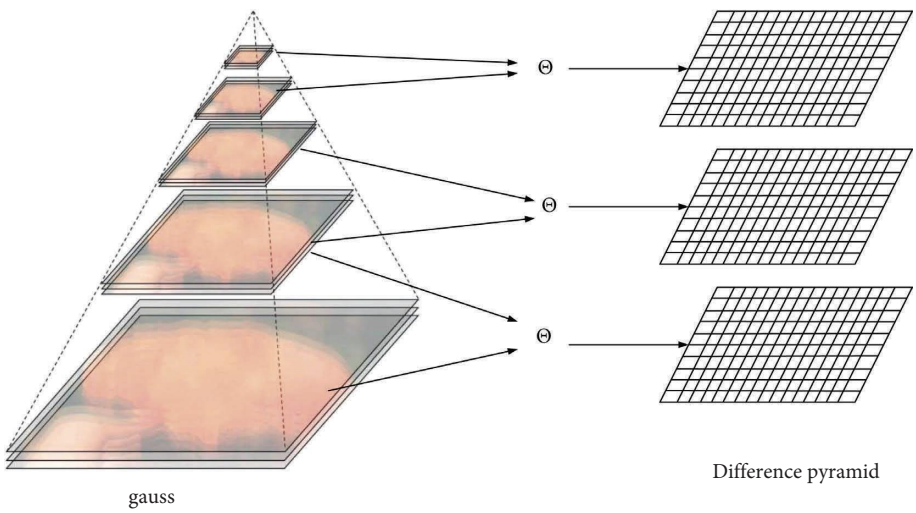

Figure 2: Generation of differential pyramid.

$$k = 2^{1/S}. \tag{5}$$

Whenever the value of parameter σ is doubled, the image of scale 2σ is downsampled by a factor of 2 as the bottommost image of the next set.

In order to find the extreme points in the DoG scale space, each point in the DoG is compared with 8 points around it and 9 points in the upper and lower layers. Only the point that is the maximum or minimum value of the 27 points [15] will be recognized as a feature point, as shown in Figure 3.

In the figure, X represents the current point, and the blue clouds represent the surrounding points.

The difference pyramid constructed according to the previous steps can search for local extreme points from the discrete spaces. The so-called discrete spaces refer to the results obtained by sampling from a three-dimensional continuous space. The extreme point searched in the discrete spaces may not be the final extreme point. It also needs to filter the searched feature points in the subsequent steps and eliminate the points that do not meet the constraints [16]. After the feature points are selected, appropriate filtering processing can be performed to fit the nearby data to find the position, scale, principal curvature, and so on. This step can filter out feature points with low contrast and unstable response to edges. The realization of this process is to perform Taylor series expansion on the original Gaussian difference, as shown in the following formula:

$$D(x) = D + \frac{\partial D^T}{\partial x}\Delta x + \frac{1}{2}\Delta x^T \frac{\partial^2 D}{\partial x^2}\Delta x. \tag{6}$$

The Δx in (6) represents the offset of the sample point. Since x is an extreme point on $D(x)$, deriving the above formula, let its derivative be 0, and get the following formula:

$$\Delta x = -\frac{\partial^2 D^{-1}}{\partial x^2}\frac{\partial D(x)}{\partial x}. \tag{7}$$

It then brings the obtained Δx into the Taylor expansion of $D(x)$ to obtain the following formula:

$$D(\hat{x}) = D + \frac{1}{2}\frac{\partial^2 D^T}{\partial x}\hat{x}. \tag{8}$$

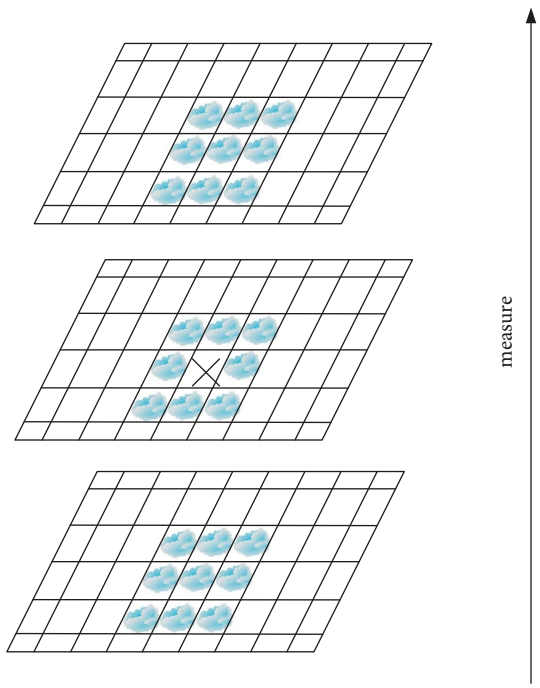

Figure 3: Local extreme points of the current image.

It sets the contrast threshold T, usually 0.5. If $|D(\hat{x})| \geq 0$, the feature point is retained; otherwise, it is eliminated.

The SIFT algorithm reacts strongly to image edge regions. Therefore, removing these feature points along the edge of the image is also necessary to improve the stability of the algorithm. The principal curvature of the edge gradient direction is much larger than the principal curvature along the edge direction, which can be considered as an inferior feature point, which is also a point that must be deleted in this paper [17]. The $D(x)$ of the candidate feature points can be simply calculated with the second-order Hessian matrix H, because the eigenvalues of the Hessian matrix are proportional to the principal curvature $D(x)$. H is defined as follows:

$$H = \begin{bmatrix} D_{xx} & D_{xy} \\ D_{xy} & D_{yy} \end{bmatrix}. \tag{9}$$

Among them, D_{xx}, D_{xy}, and D_{yy} are obtained from the corresponding position difference of the candidate point neighborhood, respectively. This paper does not care about the specific values of the eigenvalues but only focuses on the ratio of the eigenvalues.

In $r = \alpha/\beta$, α and β represent eigenvalues in different directions. The sum of eigenvalues can be represented by the trace of the matrix [18]. The product of eigenvalues can be represented by the value of the determinant of the matrix, so there is the relationship of the following formula:

$$\frac{Tr(H)^2}{\mathrm{Det}(H)} = \frac{(r+1)^2}{r}. \tag{10}$$

Among them, $Tr(H)$ is the trace of the matrix, and $\mathrm{Det}(H)$ is the determinant of the matrix. When the eigenvalues in different directions are equal, the numerical result of this formula is the smallest and has a positive correlation with the ratio [19]. Therefore, only by judging the following formula, it can be concluded whether the principal curvature is smaller than the threshold value T_r.

$$\frac{Tr(H)^2}{\mathrm{Det}(H)} > \frac{(T_r+1)^2}{T_r}. \tag{11}$$

If (11) holds, this means that the principal curvature is greater than the threshold, that is, the inferior feature points mentioned above. After this series of filtering, this paper can obtain the same feature points from different perspectives. Now, this paper can restore the three-dimensional information of the scene through feature point matching under multiple views. It should be pointed out here that the SIFT algorithm is not the only way to find feature points.

The SIFT algorithm also assigns the scaling and rotation of the feature points. It uses the gradient magnitude and direction of the image scale space where the feature is located to determine the relevant parameters. These values are used in subsequent feature descriptor calculations. This is beneficial for this paper to calculate the correspondence of features in different images [20].

In order to ensure the rotation invariance of the rotation vector, the original coordinate axis needs to be rotated around the feature point. After defining the rotation angle size as θ, the new coordinates of the image pixel points can be expressed in the form of matrix multiplication, as shown in the following formula:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}. \tag{12}$$

When the coordinate axis is rotated to be consistent with the main direction of the feature point, it takes the feature point as the center to take a window with a length of 8 pixels, as shown on the left of Figure 4. The center of the window represents the location of the key point, and each square represents a pixel of its neighborhood in the specified scale space. The arrows in the squares represent the direction of the pixel gradient, and the length indicates the magnitude of the pixel gradient. It then performs a weighted operation on the pixel gradient through Gaussian filtering, and finally a square with a length of 4 pixels can be counted into a gradient histogram of 8 dimensions. After calculating the cumulative value of each dimension, seed points in 8 directions can be formed, as shown on the right of Figure 4. The results obtained in this way combine the information of the pixels around the feature points. It can effectively enhance the anti-noise ability of the algorithm and is more robust to matching pairs with positioning errors.

The previous matching stage in this paper finds the common points in the corresponding image pairs. However, this paper cannot guarantee that the matching pairs found are 3D corresponding points in the real scene, and there may be outliers. It is necessary to find a geometric transformation that can map enough common points in the two images. If such a geometric transformation exists, the two images are

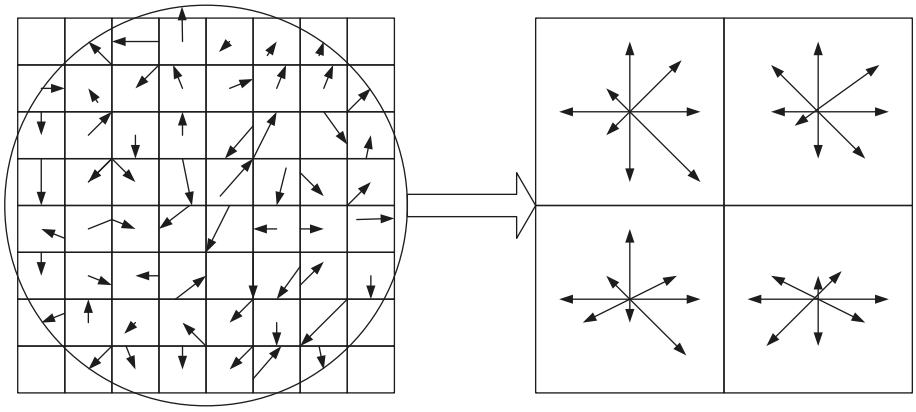

Figure 4: Pixel gradient statistics to generate key point descriptors.

considered geometrically validated. This means that the geometry of these points in the scene also needs to have a one-to-one correspondence between these two graphs. Depending on the spatial information obtained in the images, different methods can be used to describe the geometric relationship between them. A homography transformation can be used to describe the transformation between two images of a camera that acquires a flat scene. Its epipolar geometry is used to represent the geometric relationships that exist between the same spatial point, different camera positions, and projections on the camera's image plane. Figure 5 shows the spatial relationship between the spatial point and the projection plane. Point P represents a point in three-dimensional space, O_t and O_r represent the position of the optical center of the camera at different shooting angles, and P_r and e_r are called epipolar lines. The essential matrix E is a 3×3 sized matrix containing the epipolar geometry. If the camera calibration internal parameters are known, the epipolar geometry allows the motion of the camera to be described by the essential matrix E, and the relationship between the two epipolar lines of the binocular image is obtained. The essential matrix is solved as follows.

R and T represent the rotation matrix and translation matrix experienced by the camera from O_t to O_r, respectively. It defines an obliquely symmetric matrix, as in the following formula:

$$S = \begin{bmatrix} 0 & -T_Z & T_y \\ T_Z & 0 & -T_x \\ -T_y & T_x & 0 \end{bmatrix}. \tag{13}$$

In Figure 5, vectors P_r and P_l represent the positions in their respective camera coordinate systems, and the relationship is as shown in the following formula:

$$P_r = R(P_l - T). \tag{14}$$

Multiplying the left and right sides of (16) by $P_r^T S$ yields the following formula:

$$P_r^T \mathrm{RSP}_l = 0, \tag{15}$$

$$E = RS. \tag{16}$$

It usually defines formula (18) as the essential matrix, resulting in the following formula:

$$P_r^T E P_l = 0. \tag{17}$$

Since the feature correspondences in the feature matching stage always contain outliers, it is necessary to use robust estimation methods to screen feature points in geometric validation, such as Random Sample Consensus. The output of this stage is referred to herein as the scene graph, and the nodes of the graph represent images. The edges of the graph connect image pairs that are geometrically validated.

4.2. Feature Extraction Effect. In order to obtain a 3D model with better reconstruction effect, this paper compares three mainstream reconstruction algorithm benchmarks. The three methods of motion structure recovery and multi-view reconstruction are VisualSFM + PMVS, COLMAP + OpenMVS, and OpenMVG + OpenMVS, as shown in Table 1.

As shown in Table 2, in order to comprehensively compare the performance of the algorithms, this paper compares the four performances of reconstruction speed, reconstructed point cloud number, reconstructable category diversity, and reconstruction stability. In this paper, four different types of clothing were selected in the experiment, and 60 images were taken evenly around the model. The paper uses the image input of the pattern to combine different reconstruction processes to compare the reconstruction effect.

From the statistical results of the number of dense point clouds in Figure 6, among the results of the four types of clothing, the reconstruction process of

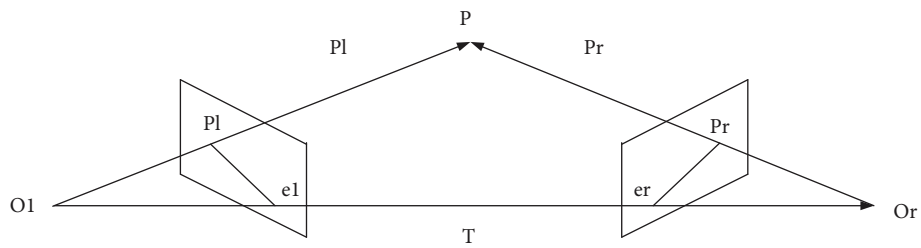

Figure 5: Epipolar geometric space relationship.

Table 1: Methods for multi-view reconstruction.

Serial number	Way
1	VisualSFM + PMVS
2	COLMAP + OpenMVS
3	OpenMVG + OpenMVS

Table 2: Experimental comparison indicators.

Contrast index	Rebuilding object
Reconstruction speed	Casual suit
Number of reconstructed point clouds	Sports coat
Reconfigurable category diversity	Striped t-shirt
Reconstruction stability	Pure black long sleeve

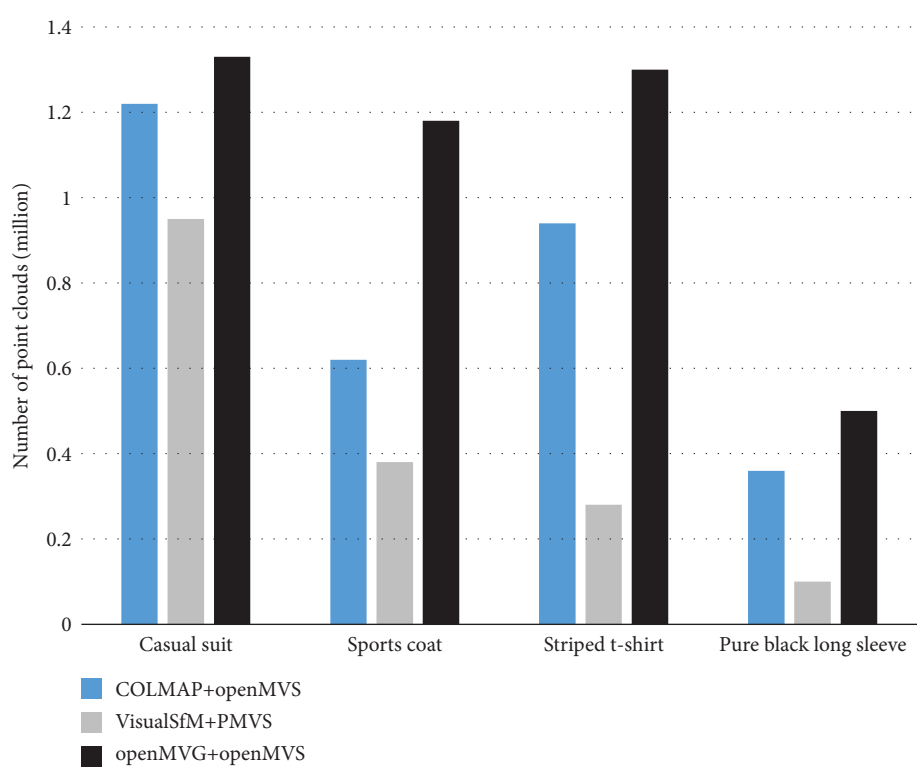

Figure 6: Comparison of the number of point clouds for different clothing types and reconstruction processes.

OpenMVG + OpenMVS has the largest number of point clouds. Among them, regardless of the reconstruction process, the number of point clouds reconstructed by pure black long sleeves is much lower than those of the other three types of clothing. Combined with the analysis of the reconstruction effect above, for solid-color clothing or clothing lacking texture information, the use of 2D images to reconstruct 3D models is more prone to the problem of

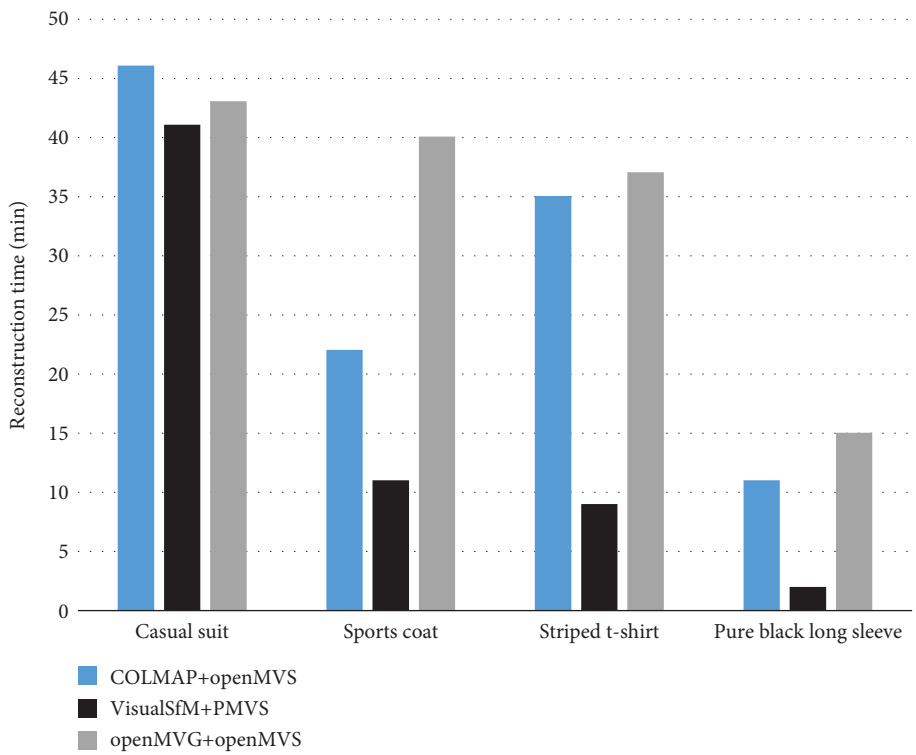

Figure 7: Comparison of reconstruction time for different clothing types and reconstruction processes.

missing model point clouds. For casual suits, although the color is single, the surface of the clothing is rougher than the black long sleeves. There are many rough fibers attached to its surface, which is more conducive to finding feature points. This means that clothing with richer texture or color information is more suitable for reconstructing the 3D model of clothing in this way. A careful observation of the data in Figure 6 shows that for casual suits, there are differences in the number of point clouds obtained by the three reconstruction processes. However, the number of point clouds can basically reach the order of millions, and the gap is not obvious. However, when reconstructing clothing types with less texture information, such as sports jackets or striped T-shirts, the number of point clouds obtained by OpenMVG + OpenMVS far exceeds those of the other two reconstruction processes. This also shows that such algorithmic processes are more robust to clothing diversity.

The hardware processor used in this experiment is configured as Intel Core i5-6600K. Figure 7 shows that the increasing trend of reconstruction time is consistent with the number of point clouds. In order to explore the reconstruction efficiency of various reconstruction processes, this paper uses statistics to reconstruct the time spent on each million point clouds of various clothing models and then compares the average values. The calculation shows that the reconstruction process OpenMVG + OpenMVS takes an average of 34.4 minutes to reconstruct a million point clouds, which is the shortest among the three. For the exploration of the reconstruction stability performance, in this experiment, all kinds of experiments were repeated three times, and the reconstruction time was nearly the same as the reconstructed point cloud effect. This shows that there is no significant difference in the reconstruction stability of the three reconstruction processes, they are all relatively stable, and the data results are no longer given separately.

5. Development and Innovation of Fiber Art Design

5.1. Pseudo 3D Display Technology Based on 2D Images. Showing fiber art with its two-dimensional images lacks authenticity. The product can only be observed from a fixed angle, and the interaction between the user and the artistic design cannot be realized. The use of 2D images to build 3D models can effectively make up for these shortcomings. But this method has many steps from shooting to 3D reconstruction. This cannot meet the requirements of rapid deployment and is more suitable for offline modeling application scenarios.

The product display based on image photo stream has been studied by scholars as early as ten years ago. This method is based on the object to be displayed and rotates the object by 360 degrees. It takes multiple images according to different precisions, and through image analysis and processing and adding interactive functions, the pseudo three-dimensional display effect of commodities is realized. In fact, if the avatar in this photo stream can be replaced with the user's avatar, the fitting effect will be closer to the photo stream effect of the user's real fitting. In view of this, this section first introduces the realization of clothing display based on photo stream. It then describes how to achieve

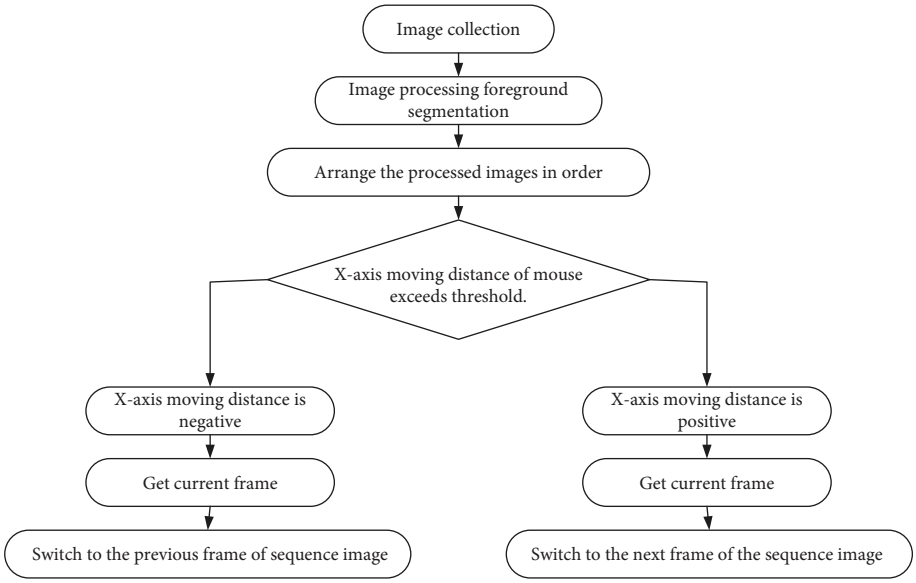

Figure 8: The display process of fiber art design based on HTML5.

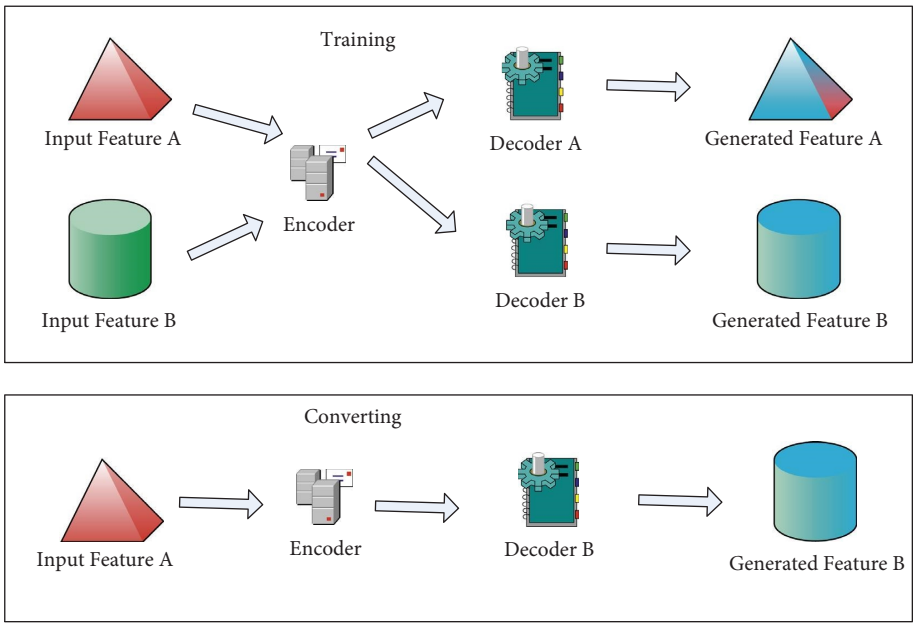

Figure 9: Model training and conversion process.

a personalized display of the dressed human body through "face swapping" technology.

In this experiment, a mobile device is used to collect the target image, so this paper first imports the captured image into the PC and then uses GraphCut to remove the background of the image. It only retains models wearing clothing and adjusts details such as color and light to avoid poor display effects due to changes in light during shooting. This display method can be easily embedded into the HTML file to achieve interaction with the user. The specific implementation process is shown in Figure 8.

5.2. Training and Transformation Analysis. Usually, in such an encoding and decoding process, the neural network is trained to reduce the error between the predicted value and the true value. This results in a weight matrix that satisfies the transformation requirements, the training process of which is shown in Figure 9.

Different from the evaluation indicators of traditional neural networks, the "transformation" task cannot simply use the magnitude of the loss value to determine the quality of the model. Therefore, it is common to define encoder A and encoder B losses separately. The values of both represent

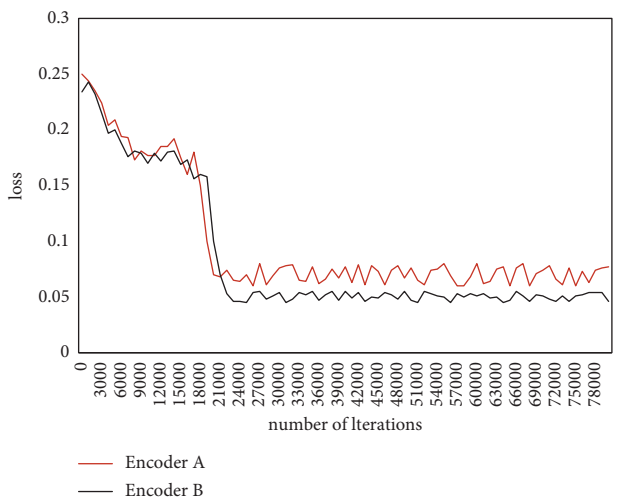

Figure 10: Loss curve of the encoder-decoder network.

how well the network reconstructs the input image. The details are as follows, where functions $g\theta_1$ and $g\theta_2$ represent the encoder and decoder, respectively; x is the image input to the encoder; and h is the intermediate vector obtained by the encoder. $\hat{x}$ represents the output obtained by decoding with h as input, and the autoencoder loss is defined as the difference of $\hat{x}$ between the input x of the model and the output. The calculation formulas are as follows:

$$\begin{aligned} h &= g\theta_1(x) \\ &= \sigma(W_1 x + b_1), \end{aligned} \tag{18}$$

$$\begin{aligned} \hat{x} &= g\theta_2(h) \\ &= \sigma(W_2 x + b_2), \end{aligned} \tag{19}$$

$$J_E(W, b) = \frac{1}{m}\sum_{r=1}^{m} 1/2\left\|\hat{x}^{(r)} - x^{(r)}\right\|. \tag{20}$$

And for the transformation task, the model needs to restore image B from the vector encoded by image A. Since there is no so-called ground-truth label, this experiment cannot define a numerical loss for how good the conversion result is. It can only judge the quality of model training by continuously observing the conversion effect. That is, it is judged whether the model has learned an effective weight matrix by observing the loss value. Figure 10 shows the loss curve during the training process of this experiment. It can be seen that when the number of iterations exceeds 20,000, the value of the loss function has not decreased significantly. At this point, the gradient has basically stopped decreasing, which means that the training can be terminated.

Based on a large number of experiments, the mini-batch used for training is finally set to 64. The initial learning rate is set to 0.001, and the learning rate is set to decay to 10% of the learning rate itself every 10 epochs.

6. Conclusions

The design of art is to innovate, and the same is true of fiber art. Today, with the development of network technology, the innovation of fiber art design should also be combined with the technology of the times. Starting from the current research background of fiber art, this paper puts forward the research significance of this paper from the visual and tactile dimensions of fiber art. Afterwards, a comprehensive analysis of the visual and tactile dimensions of fiber art is carried out. Furthermore, a related feature selection algorithm is proposed based on the design of fiber art, and the effectiveness of the algorithm is proved. Finally, for the design exhibition of fiber art, a three-dimensional simulation display of two-dimensional images is proposed. The experimental results show that the algorithm in this paper is effective. However, there is also room for improvement in the research; that is, the fiber art can be classified into different periods of art, and the results can be more universal.

Data Availability

Data can be obtained by contacting the corresponding author under reasonable requirements.

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

Heterogeneous Hadoop Cluster-Based Image Processing Workload Distribution Framework between CPU and GPU

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Due to the rapid development of image data and the necessity to analyze it to extract meaningful information, heterogeneous systems have gained prominence. One of the most critical aspects of distributed systems is load balancing. When it comes to the distribution of workload in a balanced manner in a cluster, some heterogeneous systems are used for image processing. When workloads are allocated in these systems, the computational power of the processors is not considered. As a result, in these heterogeneous systems for image processing applications, an uneven workload distribution issue is found. A workload distribution programming framework is presented and discussed in this paper. The proposed strategy consists of two parts. As a first step, image data is split into optimal split sizes and distributed across nodes, then the image data is distributed across CPU and GPU in a second step for processing. A heterogeneous environment is created by combining the CPU and GPU. The OpenCL Java bindings are used to set up both the CPU and GPU to run the program. To assess the performance of the suggested technique, certain tests are carried out and compared to current platforms. For image processing applications in heterogeneous clusters, the proposed workload distribution approach distributed image data efficiently. The results of the proposed solution (Hadoop + GPU) show that using an effective workload allocation mechanism in heterogeneous systems reduces average execution time while improving overall application performance.

1. Introduction

A vast quantity of digital data is created everywhere in today's technology world from many sources such as the Internet, networked cameras, mobile phones, sensors, and so on. Digital data used to be measured in Megabytes and Gigabytes, but today it is measured in terabytes and petabytes. Because 70% of digital data is unstructured, such a large volume of data needs additional storage and processing power [1]. Unstructured data includes images, which are a two-dimensional representation of pixels with variable intensity values, among other forms. In addition, images include intrinsic data-level parallelism that must be handled to extract relevant information, a process termed image processing. It is useful in a variety of applications, including medical imaging, satellite imaging, document analysis, and so on.

The constraints of limited memory capacity and data access speed arise when storing such a vast amount of data on a single processing device, impacting the performance of the application. Due to these problems and the programs' high computing demands, it was impossible to improve the performance of a single CPU or processing system. Due to the need to maximize the efficiency of running data independently of one another across several computing units in parallel, distributed and parallel architectures had to be developed.

Hadoop is a well-known and simple-to-use technology with a loosely linked design and distributed environment. The Hadoop Distributed File System (HDFS) and the MapReduce programming methodology make up Hadoop. Google's file system (GFS) is based on HDFS, which is a free and open-source version of it. In essence, it uses a map-reduce method to distribute enormous amounts of data across commodity computers, which is used by a variety of companies including Yahoo, Amazon, Facebook, and Google. The maps reduction technique provides dependable data synchronization, load balancing, as well as dynamic allocation of jobs among multiple, compute units.

The GPU architecture is configured so that the hardware has several multiprocessors. Each multiprocessor is composed of a collection of SIMD (Single Instruction Multiple Data) architecture-based 32-bit processors. Every clock cycle, a multiprocessor executes the same instruction on a group of threads known as a warp. The quantity of threads in the warp determines the size of the warp. Each streaming multiprocessor (SM) has 8 scalar thread processors (SP), and the block's threads share 16 kb of on-chip memory for communication. Programmers write two different types of code for GPU execution: kernel and host code. The kernel code is executed concurrently on the GPU. The CPU's host code manages data transmission between the GPU and main memory, as well as starting kernels on the GPU.

Massive parallel processing cores combined with GPU are provided by heterogeneous clusters, which give high speed and scalability data dissemination to faraway consumers. Because of the commodity PCs' network and GPU capability, it is adaptable. Heterogeneous computing is the utilization of heterogeneous architectures by applications. Figure 1 demonstrates how heterogeneous architectures are made up of various processor types, each of which has a distinct set of advantages and disadvantages, such as GPUs and CPUs with multiple cores. A variety of hardware can be used on these platforms, varying in power consumption and performance [2]. As a result, heterogeneous systems improve performance while lowering energy usage [3].

1.1. Problem Statement. By efficiently processing a vast amount of image data, state-of-the-art heterogeneous frameworks for image processing applications provide high performance. It is important to note that for these techniques to achieve good application performance, they need a minimum amount of support to distribute data between nodes and between CPUs and GPUs based on processing power. Nevertheless, this can be achieved by utilizing a load balancing technique that divides and distributes data between the nodes as well as between the CPU and GPU on each node, depending on their computational capabilities. As a result, an effective workload allocation policy must be implemented to improve application performance.

1.2. Aims and Objectives. The following aims and objectives are deemed to support the problem description and will take us to the desired goal:

(i) To give programmers an easy-to-use image processing framework that automatically distributes workload over a heterogeneous cluster, resulting in improved performance

(ii) Within the node, automatically partition image data between CPU and GPU

1.3. Contributions

(i) A new method for partitioning data into optimal split sizes which ensures locality for computations by ensuring that images within the given split cannot exceed the boundaries of the split

(ii) To maximize resource efficiency and minimize data transfer, splits are dispersed across nodes and within nodes according to their computational capabilities

(iii) Instead of acquiring expensive supercomputers or specialist vector machines, a commodity computer systems cluster can readily manage huge amounts of image data

The rest of the paper is organized as follows:

Section 2 describes the literature review, Section 3 proposed the framework, Section 4 is results and analysis while Section 5 contains the conclusion and future work.

2. Literature Review

It aims to provide image processing in a heterogeneous environment by combining multicore CPU and GPU methods. In a heterogeneous cluster, diverse computing capability processors are paired together to offer a programming framework that allows for an optimal split size, even/balanced job assignment, and maximum resource efficiency.

2.1. Image Processing in a Distributed Environment. In image processing applications, distributed systems have quickly become the preferred platform because of their fast-processing speed, scalability, and efficiency. It is feasible to handle large quantities of uploaded image data using distributed systems. Due to the growth of distributed systems, applications with large storage and processing needs are becoming more and more popular. Data sharing, device sharing, device connectivity, and task distribution flexibility are all advantages of distributed systems versus single processor systems. Many open-source programming paradigms, such as Spark, have been created to assist in efficient data processing in distributed environments [7],

The UC Berkeley MapReduce and Storm6 Spark [4] tools allow appealing computations such as data mining and machine learning. The storm is a distributed real-time computing system that successfully handles unbounded data streams. The MapReduce architecture is a popular choice for large data analysis because of its capacity to handle semi-structured and unstructured data in parallel [2].

In addition to image processing applications [5], face and gesture recognition [6], face tracking [7], video

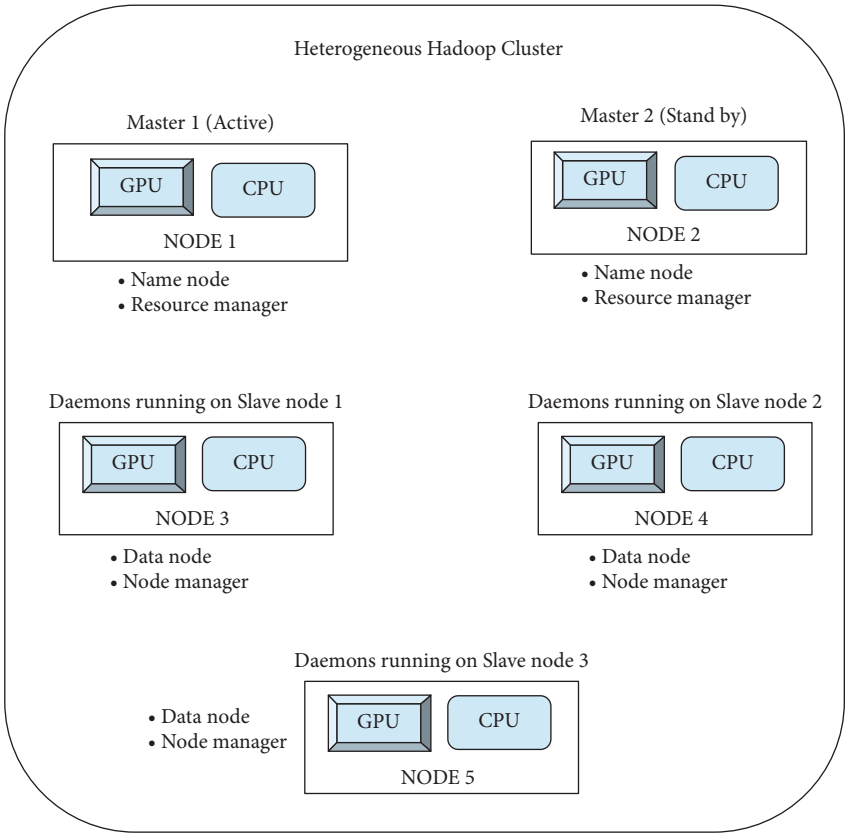

Figure 1: A generic diagram of the heterogeneous Hadoop cluster.

detection of textual words from online lecture videos [9], as well as video surveillance [10], the Apache Hadoop framework has been used in many other applications. The Hadoop MapReduce architecture was used to create a satellite image application for a Qatari environmental study center [11]. Hadoop has also been used to manage enormous amounts of image data in content-based image retrieval (CBIR) [12].

2.2. GPU-Based Image Processing. Using the OpenGL graphics library, the GPU was employed for feature extraction and tracking [13]. GPUs have been employed in applications such as Canny edge detection [14], satellite image processing [15], and medical image processing [16]. The GPU is faster than the CPU at processing the integral of photos, as shown in a study of face detection using the viola-jones method [17]. When image data is generated in real-time from satellites and must be processed fast, GPUs have been employed for image smoothing [18] and cloud removal [19] operations. It has been demonstrated that GPUs can be used in the medical field to detect brain tumor cells, complete several stages of operations, and provide fantastic performance when processing large amounts of image data rapidly [20].

2.3. Image Processing Using Heterogeneous Hadoop Clusters. Using parallel processing cores and GPUs, heterogeneous clusters assist in delivering data at high speeds and scalability to distant consumers [21]. To effectively analyze large amounts of data, the CUDA on the Hadoop framework was employed [22], which improves application performance by combining Hadoop's distributed computing capabilities with the GPU's high parallel processing structure [23, 24]. Mars is a framework that combines GPU capabilities with the Hadoop framework, and it is designed to process web documents (searches and logs) [25]. There are also three frameworks that combine GPU and Hadoop for high performance, though they were designed for specialized scientific tasks rather than image processing. These frameworks include MAPCG [26], StreamMR [27], and GPMR [28]. Hadoop Image Processing Interface (HIPI) was created to handle large amounts of tiny image data effectively; however, it does not support GPU [29].

3. Proposed Framework

In the section before, some of the challenges that result in an uneven work distribution in a diversified context were covered. The creation of a programming framework that can efficiently distribute data across nodes, and then within each node between CPUs and GPUs based on their processing capabilities, in a heterogeneous environment, is required to address these issues.

According to Figure 2, the proposed programming framework demonstrates how heterogeneous data may be distributed efficiently in a large amount of image data. The process involves two phases

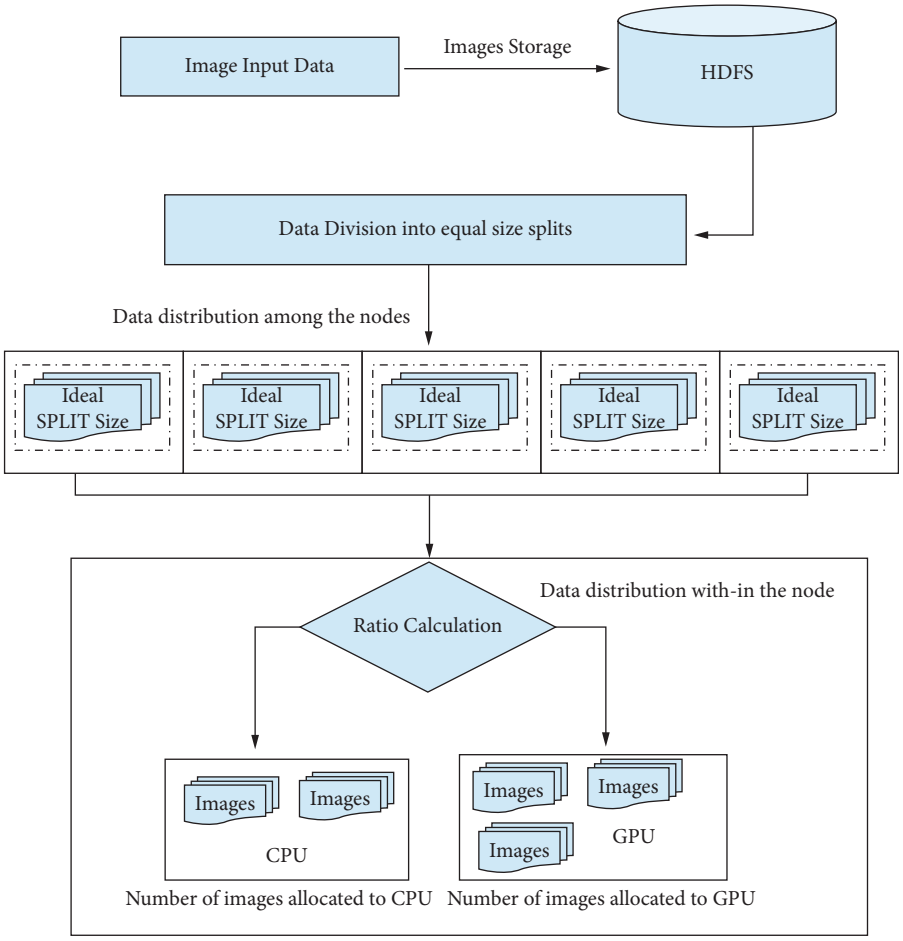

Figure 2: Proposed framework for workload distribution.

(1) Data Distribution among Nodes: the nodes in the cluster will distribute data during this phase

(2) Distribution of Workload between CPU and GPU: data is dispersed to individual nodes and then distributed within each node between the CPU and GPU in this step

This work focuses on efficiently workload distribution in a heterogeneous cluster.

3.1. Proposed Distribution of Workload among Nodes. Workloads can be divided into Hadoop workloads and cluster node workloads. The nodes process the data when it has been received. Images must be evenly distributed across cluster nodes in this study to make the best use of the cluster's processing and memory capabilities. A new distribution policy is advised for the distribution of photos. The images were chosen for the suggested technique in the same size, even if the photographs come in a variety of sizes, and each split will include one or more images. However, doing so would degrade performance because one image cannot be split into numerous parts.

Images in the proposed distribution scheme are grouped together so that every split contains many images that fit within the split size. To prevent the image from exceeding the split boundaries, the split size is determined by the image size. Figure 3 depicts several photos that have been divided and are ready to be distributed among nodes, while Figure 4 depicts the ideal split size based on the block default size.

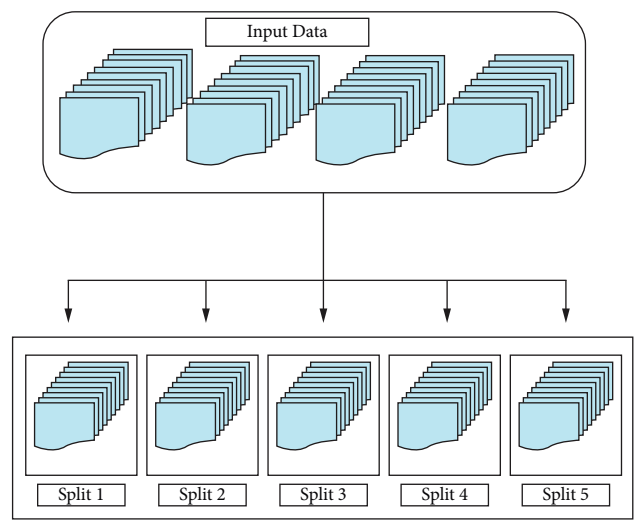

Figure 3: Partitioning data into splits.

To address the issue of uneven splits, when photos are dispersed unevenly across splits, the split size must be

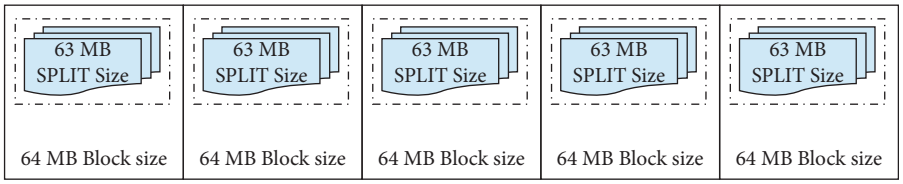

Figure 4: Partitioning image data into ideal split sizes.

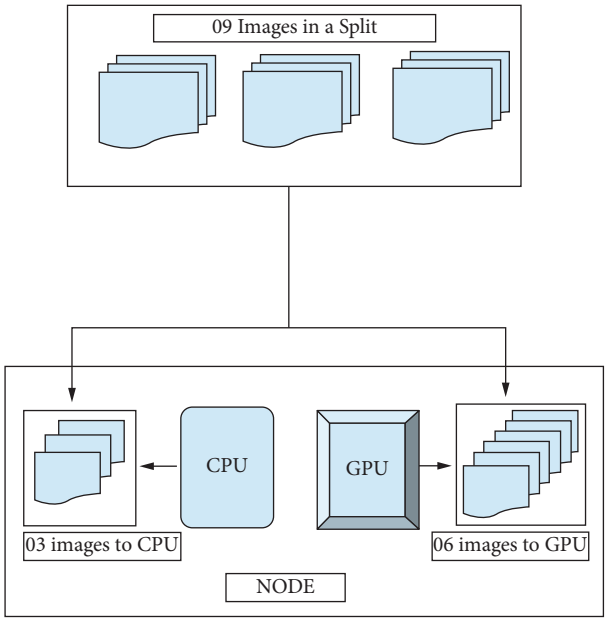

Figure 5: Data distribution within a node between CPU and GPU based on their computing capabilities.

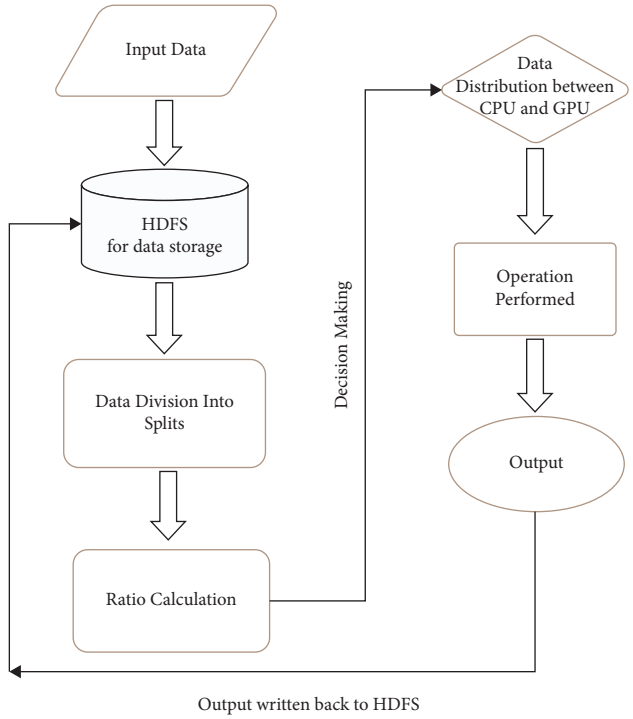

Figure 6: Basic flow chart of the proposed work.

calculated depending on the sizes of the images. When choosing an input split size in HDFS, the Input split size must be set according to the image size, then several images of the same size can be accommodated.

3.1.1. Selection of Input Split Size. The ideal input split size represents I here, the default split size represents D, the image size represents S, and no represents the maximum number of images that can be accommodated by the ideal input split. The total number of images in the dataset represents Ti, and the number of splits with an equal distribution represents Sn.

Ideal input split size = I.

Size of Image = s.

Size of Input split of default Hadoop = d.

Size of ideal split that can accommodate the number of images = no.

Divide d by s and use the floor function to disregard the fractional component to compute no. To get I, multiply s by no.

$$\begin{aligned} \text{no} &= \lfloor d/s \rfloor, \\ I &= \text{no} * s. \end{aligned} \tag{1}$$

This method computes output splits based on the size of the input image, and no image can cross two input splits.

3.2. Workload Distribution between CPUs and GPUs within a Node. A heterogeneous cluster has coprocessor GPUs, which are faster than CPUs. As a result, job assignments must be based on the processors' computational capabilities for best performance. A new effective workload allocation technique in a heterogeneous Hadoop cluster is suggested to achieve excellent performance for image processing applications.

This load balancing method is visually explained in Figure 5. This phase involves splitting up each map task into fixed-size images. The map function is called every time a split occurs, which takes an input pair of a key and value. By using the map function, each image in the split is read. By applying the proposed approach, the map function checks ratios for all images within the split and assigns images based on their computational capabilities to the CPU and GPU. A sample image is executed simultaneously on CPU and GPU to determine the execution time of both CPU and GPU on an algorithm. An image ratio is created by comparing the execution times of each processor and comparing how many

Table 1: The CPU-GPU class.

Class Public class CPU-GPU Methods	
Public static	setSplitSize() Each division size is determined using this method.
Public static	GPUDetect (float pixels, int width, int height). Processing of GPU is determined using this method.
Public void	CalculateRatio (BufferedImage bi, int width, int height). The ratio between GPU and CPU can be calculated using this method.
Public static void	Concat (BufferedImage bi, int *c*). Using this method, the images are concatenated into a single bundle.
Public static buffered image[]	Split (int *c*, int width, int height). This method divides data into equal splits.

Table 2: The ImageMapper class.

Class Public static class ImageMapper extends mapper < bundle header, image bundle, text intwritable> Methods	
Protected void	Map (bundle header key, image bundle value, context), the mapper that consumes the split and processes it is determined by this method.

Table 3: Variations in execution time (milliseconds) for CPU and GPU for edge detection.

Image resolution	CPU	GPU
1024 × 768	81	42
1600 × 900	110	50
1920 × 1080	236	61
2560 × 1440	382	69

Table 4: Average execution time (milliseconds) for CPU and GPU for edge detection.

Image resolution	CPU	GPU
1024 × 768	81	42
1600 × 900	110	50
1920 × 1080	236	61
2560 × 1440	382	69

images the GPU and CPU can process simultaneously. The Efficient Workload Distribution Implementation details process and basic flow chart of the proposed work are depicted in Figure 6 as below.

3.3. Efficient Workload Distribution Implementation. This section describes the implementation of the proposed approach.

Splits are formed by defining three variables in the setSplitSize() method of the class CPU-GPU given in Table 1. Using HDFS block size as a reference for split size calculation, one can specify the following formats for file information: (i) file size, (ii) default split size, and (iii) optimal split size. The default split size is substituted by the optimal determined split size thanks to the conf setting in run ().

The sample image, image width, and image height are the three inputs for the CalculateRatio() function, which calculates the ratio. The Concate() method is used to combine the images based on the ratio that will be sent to the GPU, the image class detail is given in Table 2. A method on the GPU called GPUdetect() is used to generate an edge detection operation based on the width, height, and the total number of pixels in an image. Once the photos have been processed, they are separated once more to separate out each individual image, which is then saved in an output file. The (key, value) pair is created by using two parameters in the map () function of the ImageMapper class to specify details about the packaged photos and their actual data, the CPU-GPU, and the ImageMapper Class are shown in Table 1 and Table 2, respectively, while the variations in execution time

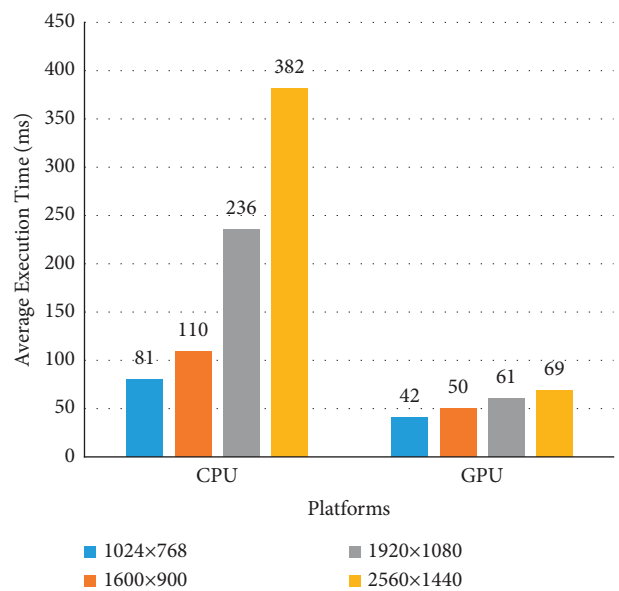

Figure 7: Average execution time (milliseconds) of CPU and GPU using a single image.

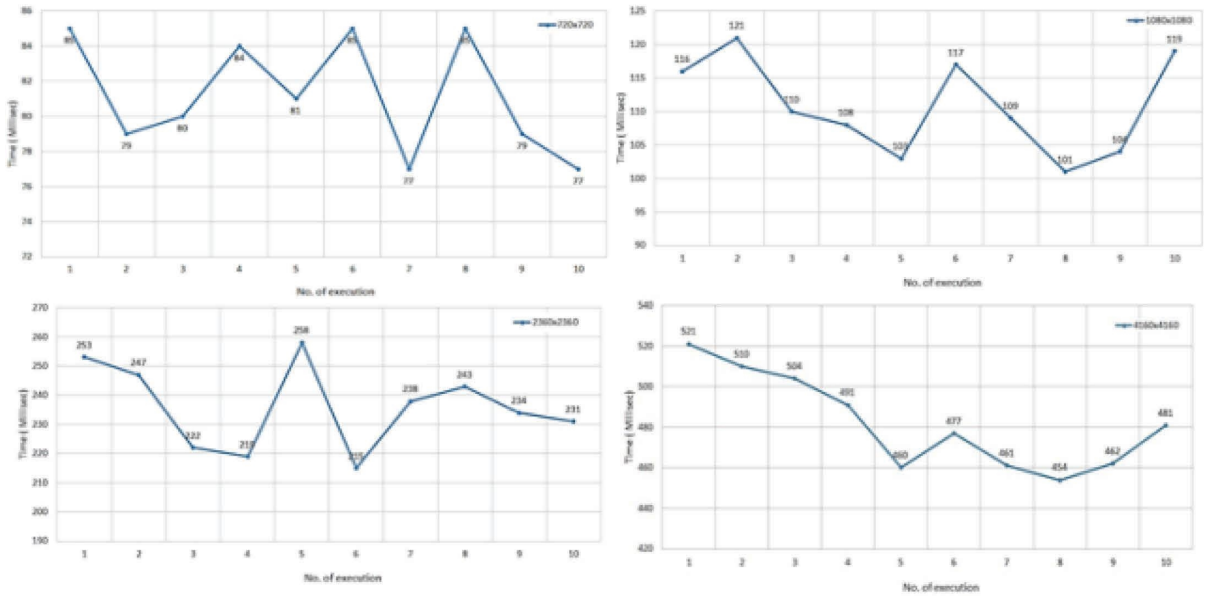

Figure 8: Variations in execution time of a single image on CPU.

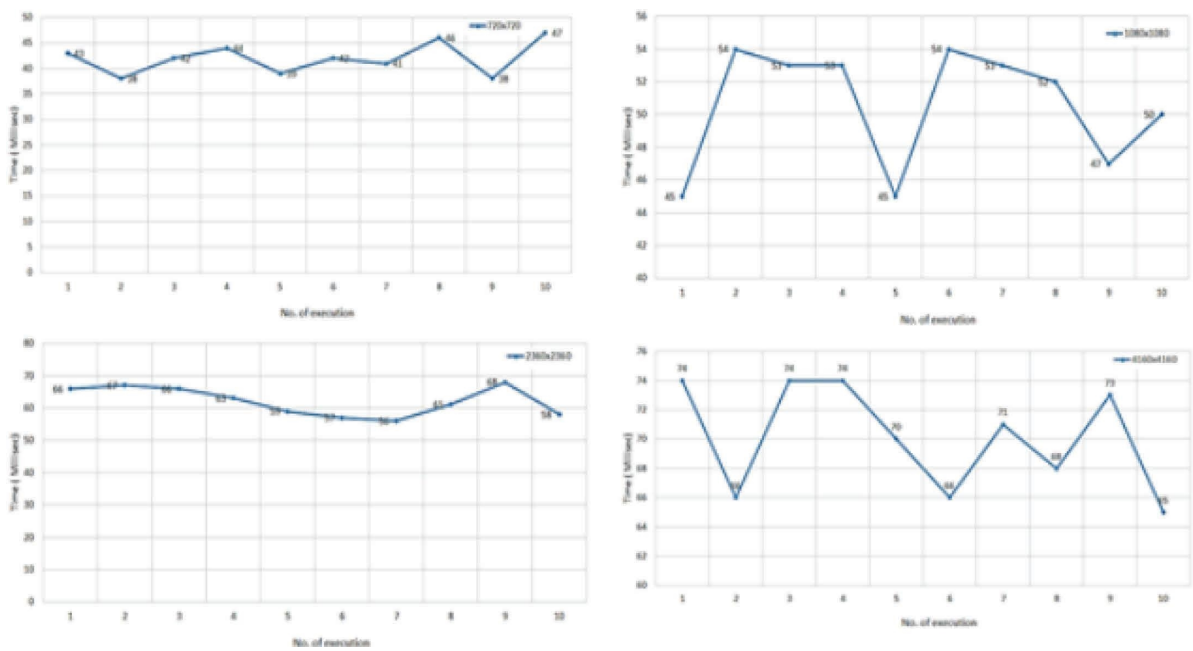

Figure 9: Variations in execution time of a single image on GPU.

(milliseconds) for CPU and GPU for Edge Detection details are given in Table 3.

4. Results and Analysis

In this section, all the results of the conducted experiments are shown and analyzed in detail.

4.1. Comparative Analysis of CPU and GPU. The results in Table 4 and a bar chart diagram in Figure 7 show the execution times for four different resolution images on a CPU and GPU, respectively, in milliseconds. In the experiment, it was discovered that when the image size rose, both the CPU and GPU execution times also increased; however, the GPU execution times increased more slowly than the exponentially rising CPU execution times. The variations in execution times for the CPU and GPU are seen in Figures 8 and 9, respectively. Table 5 demonstrates that as image size increases, the variance in GPU execution time is less than it is for CPU execution [27]. By demonstrating the effect of increasing image size on calculation time, this

Table 5: Average execution time (milliseconds) for proposed approach (Hadoop + GPU) vs existing platforms.

Resolution of image	HIPI	HIPI + GPU	Hadoop + GPU	Proposed approach (Hadoop + GPU)
1024 × 768	221	184	149	97
1600 × 900	260	225	192	133
1920 × 1080	442	371	269	172
2560 × 1440	686	489	342	191

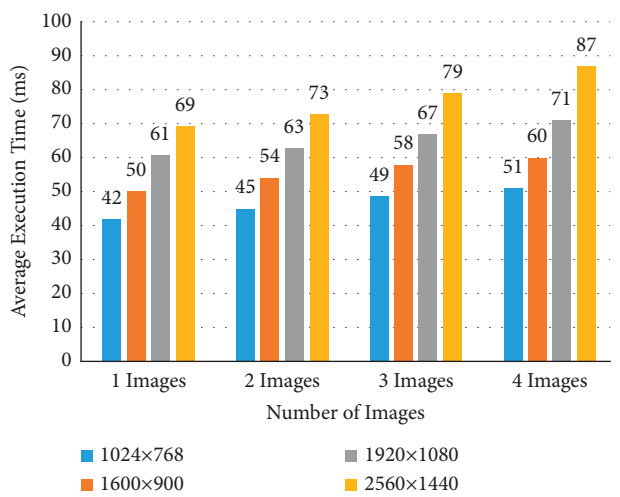

Figure 10: Average execution time (milliseconds) of an increasing number of images on a GPU.

Table 6: Average execution time (milliseconds) while scaling the number of images on a GPU.

Resolution of image	No. of images			
	I	II	III	IV
1024 × 768	42	45	49	51
1600 × 900	50	54	58	60
1920 × 1080	61	63	67	71
2560 × 1440	69	74	80	88

Table 7: Increase in execution time of an increasing number of images on a GPU.

Resolution of image	No. of images			
	I	II	III	IV
1024 × 768	3	3	3	3
1600 × 900	4	4	3	3
1920 × 1080	4	4	3	3
2560 × 1440	4	4	3	3

experiment illustrates how the GPU can be used to improve application performance by considering the overhead of loading data from CPU memory to GPU.

4.2. Varying/Increasing Number of Images on GPU. The experiment in Figure 10 demonstrates how the integration of images affects the performance of the program on a GPU. The x-axis represents the number of images integrated with each other, while the y-axis shows the execution duration in milliseconds. In Tables 6 and 7, the execution time and standard deviation for this experiment are presented by integrating four images of different resolutions (1, 2, 3, and 4 images). Based on experiments, a single image with a resolution of 1024 × 768 is processed independently in 42 milliseconds, but four images with the same resolution are combined in 51 milliseconds. According to the experimental results, the variation in execution time is directly attributed to the number of exchanges between the CPU and GPU for the transfer of each image and the subsequent writing of the result to the CPU. So, these data shifting and loading processes are executed for each individual image, but when it comes to image integration, all the integrated photos are handled in one cycle.

4.3. Comparative Analysis of Performance on Different Platforms. Figure 11 shows the average execution time for the suggested solution (Hadoop + GPU) versus current approaches. For all resolutions of photos displayed in Table 5, the suggested framework takes much less time to execute than other current frameworks (HIPI, HIPI + GPU, Hadoop + GPU). The results of the proposed solution

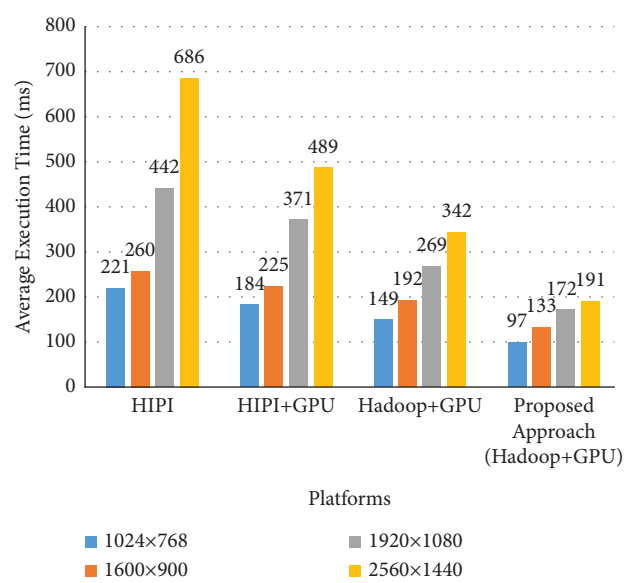

Figure 11: Average execution time (milliseconds) for proposed approach (Hadoop + GPU) vs existing platforms.

(Hadoop + GPU) show that using an effective workload allocation mechanism in heterogeneous systems reduces average execution time while improving overall application performance. Table 8 demonstrates the significant execution time variance between the suggested method (Hadoop + GPU) and the existing platforms (HIPI, HIPI + GPU, and Hadoop + GPU). The findings of the

Table 8: Time comparison between proposed approach (Hadoop + GPU) and existing platforms (milliseconds).

Image resolution	HIPI	HIPI + GPU	Hadoop + GPU	Proposed approach (Hadoop + GPU)
1024 × 768	7	10	7	3
1600 × 900	11	8	7	5
1920 × 1080	8	15	11	5
2560 × 1440	16	12	8	5

experiment show that the main factor that significantly improves application performance and completely utilizes the resources available is the suggested efficient workload allocation policy.

5. Conclusion and Future Work

The goal of this paper is to introduce a novel programming framework utilizing the Hadoop MapReduce programming model and graphics processing units (GPUs). The suggested technique offers these advantages over existing approaches for image processing applications on heterogeneous clusters. A new method for partitioning data into optimal split sizes ensures locality for computations by ensuring that images within the given split cannot exceed the boundaries of the split, to maximize resource efficiency and minimize data transfer, splits are dispersed across nodes and within nodes according to their computational capabilities and instead of acquiring expensive supercomputers or specialist vector machines, a commodity computer systems cluster can readily manage huge amounts of image data.

As a result, future work will focus on developing a split size that can easily support varied image sizes and divide them among nodes as well as inside each node between CPU and GPU. Real-time image processing refers to the completion of certain activities in a set period. In certain image processing applications, a stream of images is created that must be processed within a certain amount of time to ensure that an image does not miss its deadline. The suggested technique in heterogeneous systems will be used to process this stream of images within the stated timeframe in the future study.

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 have no conflicts of interest.

Authors' Contributions

All authors contributed equally to this study.

Acknowledgments

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Research Article

Data Protection of Accounting Information Based on Big Data and Cloud Computing

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With the rapid development of Internet technology, mankind has entered the era of big data. The Internet records all kinds of information, and the amount of information generated in the future is in a state of explosive growth. With the development of enterprises, the data of accounting information have grown, and its security has also been threatened. Once the accounting information is leaked, it will have a great impact on the company. Therefore, it is very necessary to protect accounting information data. This paper aims to study how to protect accounting information data based on big data and cloud computing. Based on this, this paper proposes an attribute-based encryption method based on big data and cloud computing and analyzes the ABE scheme of a single authority and multiple authorities. The multiauthority ABE scheme can effectively solve the problems of low computational efficiency, poor security performance, and high time overhead in the single-authority ABE scheme. The experimental results of this paper show that, under the single-authority ABE scheme in the information data protection of enterprise A, the confidentiality of data is 54% at the highest and 46% at the lowest, which is generally not very high. In the information data protection of the multiauthority ABE scheme in enterprise A, the highest data confidentiality is 86% and the lowest is 79%. The highest is 32% more than the single-authority ABE scheme. The lowest is also 33% more than that. Generally speaking, the confidentiality of its data is very high. In terms of reliability, integrity, and effectiveness, the single-authority ABE scheme is not as good as the multiauthority ABE scheme. It shows that the multiauthority ABE scheme proposed in this paper has a powerful information data security protection function and can be effectively applied to accounting information data protection.

1. Introduction

In this new century, in which the Internet and human culture are highly integrated, the rapid development of the Internet is setting off a new revolution in human beings as a whole. The Internet is infiltrating people's lives at a speed that people can barely perceive. Under the environment of network and e-commerce, the network of accounting information enables the operation of enterprises to transcend the limitations of time and space. In the management mode, it abandons the traditional accounting management mode and realizes business collaboration, remote processing, online management, and other modes. Online office, remote office, and mobile office are supported; in terms of information provision, remote reporting, remote accounting, and online information query are realized. However, due to the openness and sharing of the Internet, there are many unsafe factors in the network itself, which makes the enterprise accounting information in the network face the risk of interception, tampering, and leakage at any time.

Cloud computing is a type of distributed computing, which refers to decomposing huge data computing processing programs into countless small programs through the network "cloud." Due to the economics of cloud computing, more and more individuals and enterprises begin to deliver data storage and platform construction to the cloud, benefiting from the massive storage space and high concurrent computing power of cloud computing. The combination of big data and cloud platforms is becoming more common, which puts forward new security requirements for accounting information data in cloud computing, and the previous access control technology has problems such as

high consumption, low efficiency, and difficult management. Attribute-based encryption technology is an effective method to solve the security problem of cloud storage systems. The innovation of this paper is that it not only proposes an attribute-based encryption scheme based on cloud computing but also proposes a multiauthority ciphertext strategy. The problems of low calculation efficiency and high storage consumption of policy updates are improved, thus ensuring the security of enterprise accounting information data.

2. Related Works

With the in-depth development of the socialist market economy with Chinese characteristics, the security of accounting information and data has attracted more and more attention from the state and society. The rapid development of information technology and its application in accounting practice has endangered the security of accounting data circulating in cyberspace. The purpose of Popivniak's research was to determine how to solve the security problems that arise in accounting information, how to identify cyber threats in the field of accounting information use, and how to identify ways to prevent information theft and damage [1]. Lapitkaia found that, under the conditions of modern economic digitization, traditional accounting needs to make significant changes in the use of new information tools in order to continue to develop healthily. These new information technologies include cloud technology [2]. Pecheniuk confirmed the necessity of forming an effective information security system for enterprises. He emphasized that when designing information policies, companies must organize information security measures to be commensurate with their values, and he identified the main threats to the possible destruction of confidential information [3]. Rasheed and Kouser argued that the legal and governance environment in emerging markets is often weaker, and weak investor execution leads to a poor information environment. A corporate governance mechanism should be established in a timely manner [4]. Xing et al. raised a question whether the quality of accounting information affects capital, which has been a controversial issue. By linking the quality of accounting information with systemic risk, he found that the quality of accounting information is significantly negatively correlated with systemic risk [5]. Scholars agree that only when accounting information is properly protected can an enterprise develop healthily. If the information is leaked, it will not only lead to the loss of the company's economy but also cause the company to be maliciously competed against or even be unable to operate. The viewpoints put forward by scholars are indeed in line with the problems of enterprises in reality, but they only put forward the importance of information security and do not mention how to solve the security problem of information data.

With the rapid development of digitization and Internet technology, the amount of data on the Internet shows a trend of rapid increase. As a result, the Internet's data processing function is relatively insufficient, and many security problems have also appeared. Based on this, scholars have proposed attribute-based encryption algorithms. Francois et al. described a symmetric encryption algorithm based on a bit arrangement. The main advantage of this cryptosystem is that it can securely encrypt bit sequences and ensure the indistinguishability of the cipher. They applied the algorithm to image encryption that treats pure images as binary sequences [6]. Wang et al. proposed a new image encryption algorithm. Using his proposed pixel-swapping model to change the position of the pixels, the effect of scrambled images can be achieved. The simulation results show that the algorithm proposed by him has the characteristics of a large key space, high key sensitivity, and high security [7]. Hsiao proposed a neural network-based secure communication design method in multidelay systems in order to obtain double encryption through elliptic curve cryptography (ECC) synchronization. Its security strength depends on the difficulty of solving the elliptic curve discrete logarithm problem [8]. Luo et al. found that asymmetric, switchable, and reversible encryption is achieved by algorithmic encryption, which occupies an important position in encryption technology [9]. These scholars put forward encryption algorithms for security issues, which are consistent with the attribute-based encryption algorithm proposed in this paper, both to ensure the security of information. These scholars apply encryption algorithms to information encryption in various fields to ensure the security of data, which is worthy of reference in this paper.

3. Protection of Accounting Information by Attribute Encryption Algorithm Based on Cloud Computing

3.1. Network Accounting Information Security Issues

3.1.1. The Hidden Danger of Computer System. Computer hardware and its operating environment are important foundations to ensure the normal operation of network accounting information, and their security directly affects the security of accounting information. The security of the computer operating system is the basis of network information security. All information and security measures depend on the operating system. The vulnerability or improper configuration of the operating system may lead to the collapse of the entire security system. In order to achieve high reliability of application programs and information consistency, confidentiality, availability, and controllability on various operating systems, the system software foundation provided by the operating system must be relied on. But the security of the current operating system is not enough. The unreasonable design of computer operating system, insufficient access control, the existence of super users, and constantly discovered security holes are some of the fatal problems of the operating system.

3.1.2. Network Risks. Information plays an increasingly important role in modern economic life and has become an important means of market competition. Information has become the most important resource of an enterprise.

Whoever possesses more information and has accurate information will have a chance to win. In particular, the commercial secrets about the financial data of the enterprise are directly related to the success or failure of the enterprise.

Under illegal competition with interests and maliciousness, it is not allowed to illegally invade the accounting information systems of enterprises, and criminals who steal corporate secrets often exist. The types of malicious attacks that will appear in the information data are shown in Figure 1.

As shown in Figure 1, the current security situation of accounting information is not optimistic, the number of malicious programs is increasing year by year, and various loophole utilization technologies are constantly emerging, which would cause serious threats to the information security of network accounting. Due to the openness of Internet technology, the development of network accounting is bound to be restricted by the security of accounting information. It can be predicted that threats from all aspects of the network would gradually become the main factor affecting the security of corporate accounting information, and various high-tech network technologies would become the main force to maintain the security of corporate accounting information.

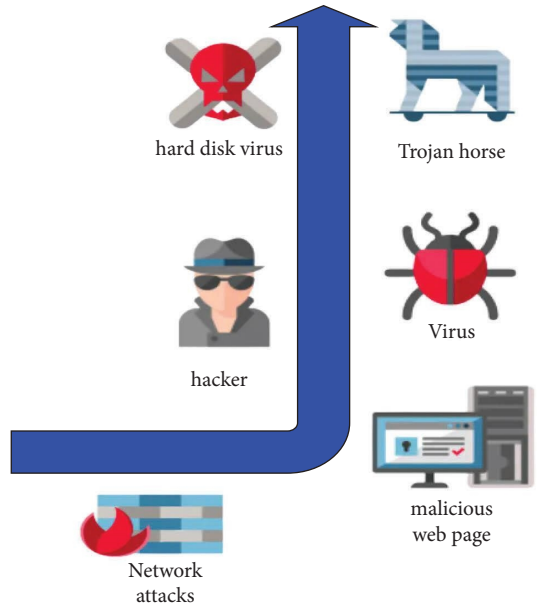

Figure 1: Types of malicious attacks.

3.1.3. Risks Brought by Data Sharing. The data-sharing method can solve the inconvenience caused by traditional accounting work, save the cost of personal and enterprise software and hardware, and promote the centralized management, preservation, and sharing of data. However, in the open cloud environment, there are difficult security issues such as data confidentiality, privacy protection, and access permission control. Data sharing is shown in Figure 2.

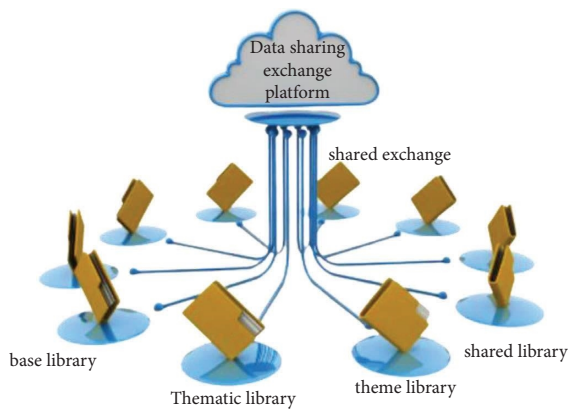

Figure 2: Data sharing.

As shown in Figure 2, faced with such problems, various technologies emerge in an endless stream, such as the traditional access layer control technology (ACL). The traditional access control technology is mainly completed through network equipment access switches, two-layer semiaccess switches, multilayer switches, and routers. However, there are several major defects in PKI technology. One is that it brings a huge user management burden to the data sender; another is that it causes data redundancy, and the encryption time is proportional to the number of data recipients. It brings about problems such as encryption time and communication consumption. Therefore, traditional encryption and access technologies are not suitable for this new cloud data-sharing model.

3.2. Attribute Encryption Algorithm Based on Cloud Computing

3.2.1. The Algorithm Proposed in the Basic Text of Attribute Encryption. In order to solve the shortcomings of traditional KPIs, technology based on attribute-based encryption (ABE) has been proposed and implemented by scholars. The attribute-based encryption technology realizes one-to-many encryption, and the data only need to be encrypted once [10]. Attribute-based encryption encrypts messages according to attributes without paying attention to the identity of the receiver, which ensures the confidentiality of the data. At the same time, the data sender does not need to manage the data user. Therefore, the time and storage overhead brought on by encryption will be reduced, and the privacy of data users will be protected [11]. The attribute encryption algorithm is shown in Figure 3.

As shown in Figure 3, attribute-based encryption technology solves the system bottleneck and data redundancy problems caused by traditional technology. In the attribute encryption mechanism, users and data can be identified by some attribute information. Both the user's decryption key and the encrypted ciphertext are associated with a series of properties. The encryption of attributes reduces the burden of user management of encryption functions and has the characteristics of flexible control, strong security, and protection of user privacy [12]. By associating attribute sets with access resources, data users can access ciphertext information according to their own

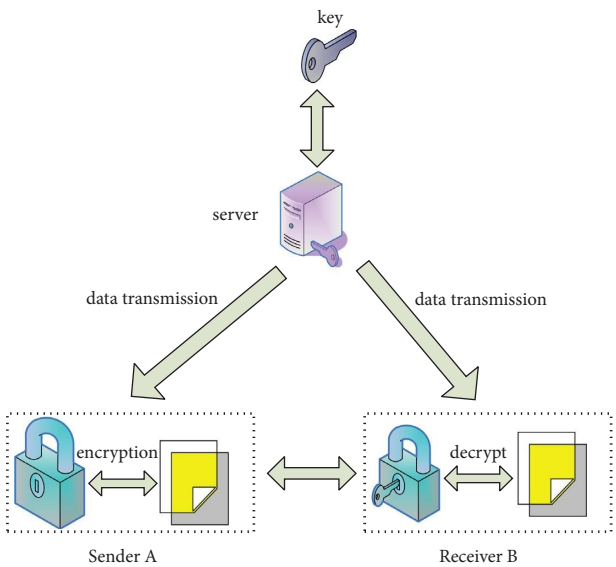

Figure 3: Attribute encryption algorithm.

authorization attributes. This technology is suitable for access applications such as private data sharing.

A finite field is a field containing only a finite number of elements. Compared with the rational number field and the real number field, it has many different properties.

Elliptic curve encryption in cryptography uses elliptic curves over finite fields. An elliptic curve over a finite field means that the curve equation is defined as follows:

$$b^2 = a^3 + ax + y. \tag{1}$$

All coefficients are elements of some finite field E_q (q is a large prime number). The most common of these are

$$E_q(a, b)\colon b^2 = a^3 + ax + y \,(\mathrm{mod}\, q). \tag{2}$$

The attribute-based encryption (ABE) mechanism only supports simple threshold control, and neither the data sender nor the data user can specify flexible access control policies [13]. The logic threshold control strategy is fast, simple, stable, and reliable, with strong practicability, high vehicle control computing efficiency, and less physical memory occupation of the controller. When the number of ciphertext attribute sets intersecting with the user attribute set is not less than the threshold set by the authority, the data user can be decrypted correctly.

The authority initially sets the threshold value d and generates the master key as follows:

$$\mathrm{MSK} = \left(b, \left\{t_i \,\middle|\, t_i \in Z_q\right\} \forall_{i \in A}\right). \tag{3}$$

The authority generates the key of user u and randomly generates a polynomial, and the user key is

$$\mathrm{SK} = \left\{D_i = g^{p(i)}\right\}. \tag{4}$$

The data sender encrypts the message with the ciphertext attribute set, and the ciphertext is as follows:

$$\mathrm{CT} = \left(A_C, E = \cdot B^S, \left\{E_i = T_i^s\right\}_{\forall_i \in A_C}\right). \tag{5}$$

The multiauthority scheme also supports key policies. Each authority generates an access tree for the attribute set and generates key components for each leaf node according to the top-down method. The user's final access policy structure is as follows:

$$T = T_1 \wedge \ldots \wedge T_N. \tag{6}$$

In the encryption algorithm, if the key is modified by an unauthorized illegal user, the encrypted data cannot be restored to the correct original information through the corresponding decryption process. In the decryption process, each T_N value is obtained in a bottom-up manner, and finally the plaintext m can be calculated and the data user can decrypt the ciphertext.

3.2.2. Key Policy Encryption Scheme. In the key-policy scheme, the data user generates an access control policy with his own attribute set, the authority calculates the user key according to the control policy, and the data sender uses the attribute set to encrypt the ciphertext [14]. When the ciphertext attribute set satisfies the access control policy, the user can decrypt it. The control strategy is constructed into a tree structure, as shown in Figure 4.

As shown in Figure 4, the various tree diagrams in the classical data structure have a typical tree structure. A tree can be simply represented as the root, the left subtree, and the right subtree. The left and right subtrees have their own subtrees. The leaf node of the access control tree T is $L(T) = A$, and the ciphertext is related to the attribute set A_{ct}. When A_{ct} satisfies T, the ciphertext can be decrypted. Access control tree: internal nodes represent a threshold; each internal node has a threshold value; and leaf nodes represent attributes [15].

A property set is set; the root node of the access tree T is R; and the access operation of the set to the access tree T node is defined as

$$T_a(A) = \begin{cases} 1, & \mathrm{attr}(a) \in A, \\ 0, & \text{Otherwise}. \end{cases} \tag{7}$$

When $T_a(A) = 1$, the set satisfies the access tree T, otherwise it does not.

The difference between the ciphertext strategy ABE and the basic ABE mechanism lies in the KeyGen and Decrypt steps. KeyGen: a polynomial is randomly generated for each node of T from top to bottom, and

$$P_a(0) = \begin{cases} b, & a = R, \\ p_{\mathrm{parent}(a)}(\mathrm{index}(a)), & \text{othrewise}. \end{cases} \tag{8}$$

Decrypt is a bottom-up recursive process, and when a is a leaf node,

$$F_a = \prod_{z \in s^*} F_Z^{\Delta_{i,s}}. \tag{9}$$

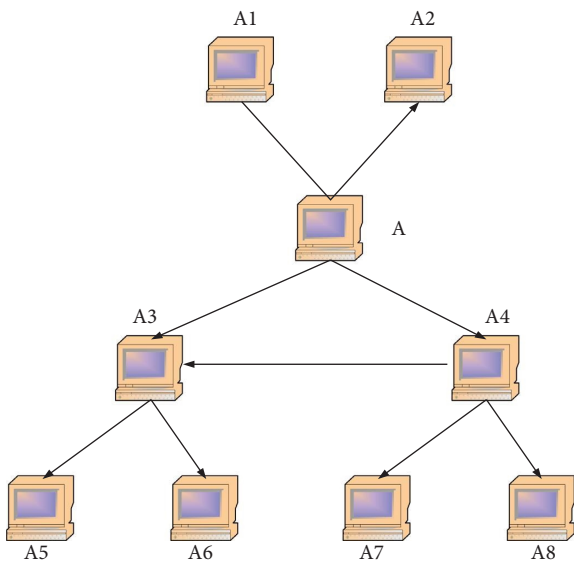

Figure 4: Access control tree.

3.2.3. Ciphertext Strategy Encryption Scheme. The outer and inner layers of a tree structure have similar structures, so this structure can be represented recursively. In the ciphertext strategy scheme, the access control strategy T is specified by the data sender, the control strategy adopts a tree structure similar to the key strategy scheme, and its leaf node is $L(T) = A_{\mathrm{ct}}$; the user key is related to the attribute set. The authorization authority generates user keys according to the attribute set, and the ciphertext policy ABE is different from the above encryption scheme [16].

The authorized agency selects a random number and calculates the master key as

$$\mathrm{MSK} = (g^{\alpha}, \beta). \tag{10}$$

The authority generates the key of user u, selects a random number for each user attribute $i \in A_{ct}$, and calculates the key as

$$\mathrm{SK} = \left(D = g^{(\alpha+r)/\beta}\right). \tag{11}$$

The data sender selects a random number and constructs an access control policy T according to the ciphertext attributes. A polynomial is randomly generated for each node a of T from top to bottom as follows:

$$p_a(0) = \begin{cases} s, & a = R, \\ p_{\mathrm{parent}(a)}(\mathrm{index}(a)), & \text{othrewise}. \end{cases} \tag{12}$$

Decryption is a bottom-up recursive process, as shown below:

$$F_a = \frac{e\left(D_{i,1}, E_{i,1}\right)}{e\left(D_{i,2}, E_{i,2}\right)}. \tag{13}$$

3.3. Attribute Encryption Scheme for Multiple Authorities. The abovementioned ABE models are all single-authorization agencies, and these models have the problem of high management cost of authorization agencies. Some scholars proposed a multiauthority attribute encryption scheme (MA-ABE) [17]. The scheme introduces GID as the user's identification in the system and introduces the central agency to manage all authorized agencies. GID is a general-purpose, adaptable, and user-friendly GUI for geometric simulation, data entry, model transformation, meshing, and visualization of results.

The MA-ABE scheme includes four algorithms: Setup, KeyGen, Encrypt, and Decrypt. Suppose that there are N authorities in the system. Setup means that each authority k chooses $B_k \in Z_q$ as follows:

$$B_k = e(g, g)^{b_k}. \tag{14}$$

Announce B_k to other authorized institutions, negotiate secretly with authorized institution j, randomly select random numbers, and define the pseudorandom function with the authorized institution as

$$\mathrm{PR}F_{k,j}(u) = g^{\left(a_k a_j / \left(s_{k,j}+u\right)\right)}. \tag{15}$$

Each authorized institution k randomly selects $N-1$ random numbers and issues them to user u through an anonymous distribution protocol. The data user u obtains the following key components as follows:

$$D_{k,j} = \begin{cases} g^{R_{k,j}} \cdot \mathrm{PRF}(u), & k > j, \\ \dfrac{g^{R_{k,j}}}{\mathrm{PRF}(u)}, & k < j. \end{cases} \tag{16}$$

The data sender encrypts the plaintext m, selects the ciphertext attribute from each authority k, and calculates the ciphertext as follows:

$$\mathrm{CT} = \left(E_0 = m \cdot B^S, E_1 = g^s\right). \tag{17}$$

MA-ABE ensures the privacy of data by means of public key encryption primitives and realizes one-to-many and fine-grained access control, so it can efficiently and securely share data in cloud environment [18]. Fine-grained is a computer programming term. The fine-grained model, in layman's terms, is to subdivide the objects in the business model to obtain a more scientific and reasonable object model. Intuitively, it is meant to divide many objects, but it has certain shortcomings. Since, in most MA-ABE schemes, the computational overhead of encryption and decryption is linearly related to the number of attributes it contains, users need to deal with a large amount of computational load, which is not good for resource-constrained devices [19]. At the same time, when the user's encrypted data in the cloud need to update the access policy, the traditional methods such as downloading and decrypting and then reencrypting and uploading are unrealistic because this will consume a lot of communication and computing resources, as shown in Figure 5.

As shown in Figure 5, in order to reduce the computational burden of resource-constrained clients and achieve rapid policy update, this paper proposes an outsourced multiauthority ciphertext policy attribute encryption scheme. Most of the existing attribute-based encryption

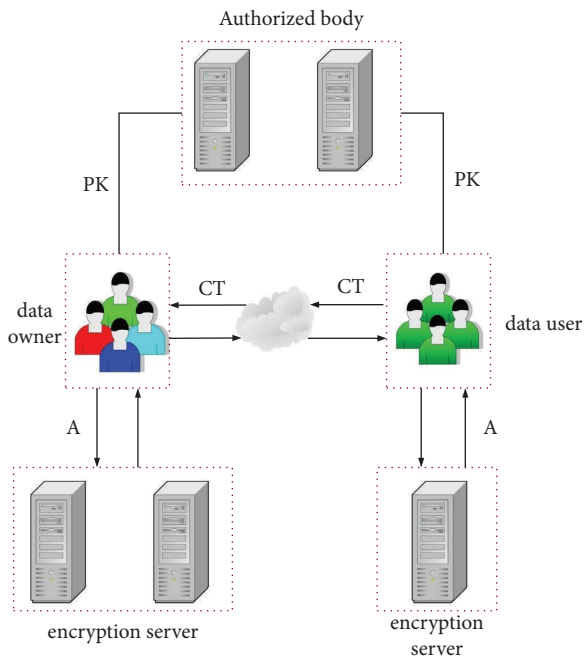

Figure 5: Multiauthority policy update outsourcing model.

schemes are based on a single authority. Once a single authority is attacked, the data security of the entire system cannot be guaranteed. In order to improve the security of the entire system, the multiauthority ciphertext strategy attribute encryption scheme appears. The system supports encryption, decryption, and outsourcing of policy updates on the client side. Under the premise of not revealing data sensitive information, most of the computing work of encryption, decryption, and policy update is outsourced to a third-party service agent, thereby greatly reducing the amount of local work. Therefore, MA-ABE is made suitable for resource-constrained devices [20, 21].

4. Results and Discussion

4.1. Test of Ciphertext Time Overhead. The symmetric elliptic curve of type A is used in the simulation experiment, which is based on a finite field of 512 bits and tested. Mainly, each step (initialization, key generation, encryption, decryption, ciphertext update, and key update) is analyzed and compared theoretically, and simulation data are analyzed and compared.

The experimental environment is built on Cygwin, which simulates a Linux environment under a Windows system. The processor is Pentium CPUG620, and the memory capacity is 4 GB. Their implementation is on a finite field of 512 bits. The experimental code is written based on the cpabe-0.11 library and the kpabe library. For the key-policy attribute encryption algorithm, the time consumption mainly comes from linear calculation. Therefore, for the time consumption of each step, only the calculation results are counted. The performance comparison of the two schemes is shown in Table 1.

Table 1: Performance comparison of the two schemes.

Steps	Single authority ABE (s)	Multiauthority ABE (s)
Initialization	3.8	1.7
Key generation	2.7	1.3
Encryption	3.2	1.0
Decrypt	3.5	1.5
Key update	3.6	0.9
Ciphertext update	4.0	1.1

As shown in Table 1, both single-authority ABE and multiauthority ABE are based on the ABE algorithm. Table 1 shows that, in terms of initialization, key generation, encryption, and decryption time, multiauthority ABEs take significantly less time than single-authority ABEs. This is because the multiauthority ABE has a linear relationship with the number of authorized institutions.

In the simulation experiment, the fixed number of authorized institutions participating is 20, the number of attributes is increased in turn, and all attributes participate in the above six steps, as shown in Figure 6.

As shown in Figure 6, in the encryption and decryption time of ciphertext, there is almost no difference in the time between the two at the beginning. But, as the data increase, multiauthority ABEs begin to outperform single-authority ABEs. This is because the single-authority ABE is linearly related to the number of attributes.

4.2. Test of Key Time Overhead. In order to verify the authenticity of the experiment, the single-authority ABE and the multiauthority ABE are tested in terms of key time overhead, and 5000 pieces of enterprise data are used for experimental analysis, as shown in Tables 2 and 3.

As shown in Tables 2 and 3, in terms of key time overhead, the single-authority ABE scheme takes more time than the multiauthority ABE scheme and its security level is not high. When the amount of data is 1000, the time spent by the single-authority ABE scheme is 5.4 seconds, while the time spent by the multiauthority ABE scheme is 2.1 seconds, which is 3.3 seconds more; when the amount of data is 5000, the single-authority ABE scheme takes 6.2 seconds, while the multiauthority ABE scheme takes 3.2 seconds. Although the time overhead of both schemes increases with the increase of the amount of data, the multiauthority ABE scheme does not change much on the whole.

4.3. Test of Algorithm Efficiency. The above is the analysis of the algorithm overhead, and then this paper analyzes the efficiency of the algorithm. Among them, due to the low efficiency of the attribute encryption algorithm, it was necessary to prove that the key generation time, encryption time, and decryption time of the test scheme in this paper are less in different environments. This article used the multiauthority ABE scheme to encrypt two text files (5 MB and 10 MB). The result is shown in Figure 7.

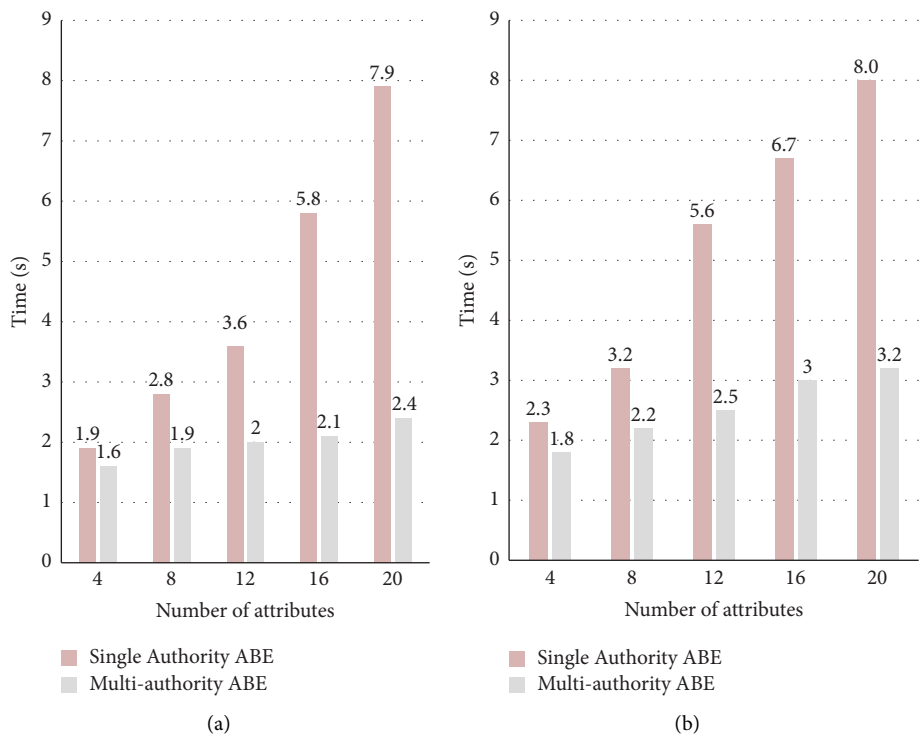

Figure 6: Two algorithms in ciphertext encryption and decryption time. (a) Comparison of ciphertext encryption time. (b) Comparison of ciphertext decryption time.

Table 2: Key time overhead of single-authority ABE scheme.

Test data	Time spent	Efficiency (%)	Degree of protection
1000	5.4	36	Generally
2000	6.8	50	Poor
3000	5.5	48	Generally
4000	5.9	39	Better
5000	6.2	45	Poor

Table 3: Key time overhead of multiauthority ABE scheme.

Test data	Time spent	Efficiency (%)	Degree of protection
1000	2.1	36	Strong
2000	2.5	50	Strong
3000	2.9	48	Generally
4000	3.0	39	Strong
5000	3.2	45	Strong

As is shown in Figure 7, the key generation time and the number of attributes have a linear relationship. With a file size of 5 MB, the multiauthority ABE scheme takes less than 2 seconds. In the case of a file size of 10 MB, although the time spent by the multiauthority ABE scheme has increased, the magnitude of the change is not large. Therefore, it can be seen that the time cost of the multiauthority ABE scheme is more advantageous.

For the encryption algorithm, the running time changes with the change of the leaf nodes in the access structure tree. The encryption efficiency of multiauthority ABE is obviously better than that of single-authority ABE because when single-authority ABE performs one exponentiation operation, single-authority ABE needs to perform two operations, as shown in Figure 8.

As shown in Figure 8, for the decryption algorithm, the efficiency of the modified scheme is higher than the original scheme because, when the multiauthority ABE performs a bilinear mapping once, the single-authority ABE performs a quadratic bilinear mapping. In addition, the sizes of the plaintext file and the ciphertext file are not much different. For simple access structures, the storage overhead can be ignored in this scheme. Through the analysis of the above execution and storage costs, the multiauthority ABE scheme is much more efficient in encryption, decryption, and key generation than the single-authority ABE scheme.

4.4. Testing of Safety Performance. The attribute encryption algorithm is a new type of encryption algorithm. Its biggest advantage is that it can use the user's identity as a key to achieve encryption. There is no longer a need to encrypt data for each decryptor like symmetric encryption, nor are there complex key management systems like public key encryption. In the ABE algorithm, the encryptor does not need to know who the decryptor is, and the decryption rules are contained in the ciphertext. The attribute encryption algorithm is more suitable for application in the cloud computing environment.

At present, user enterprises regard accounting information security as the main problem. Among security issues, users are most concerned about data security, including data confidentiality, reliability, integration, and

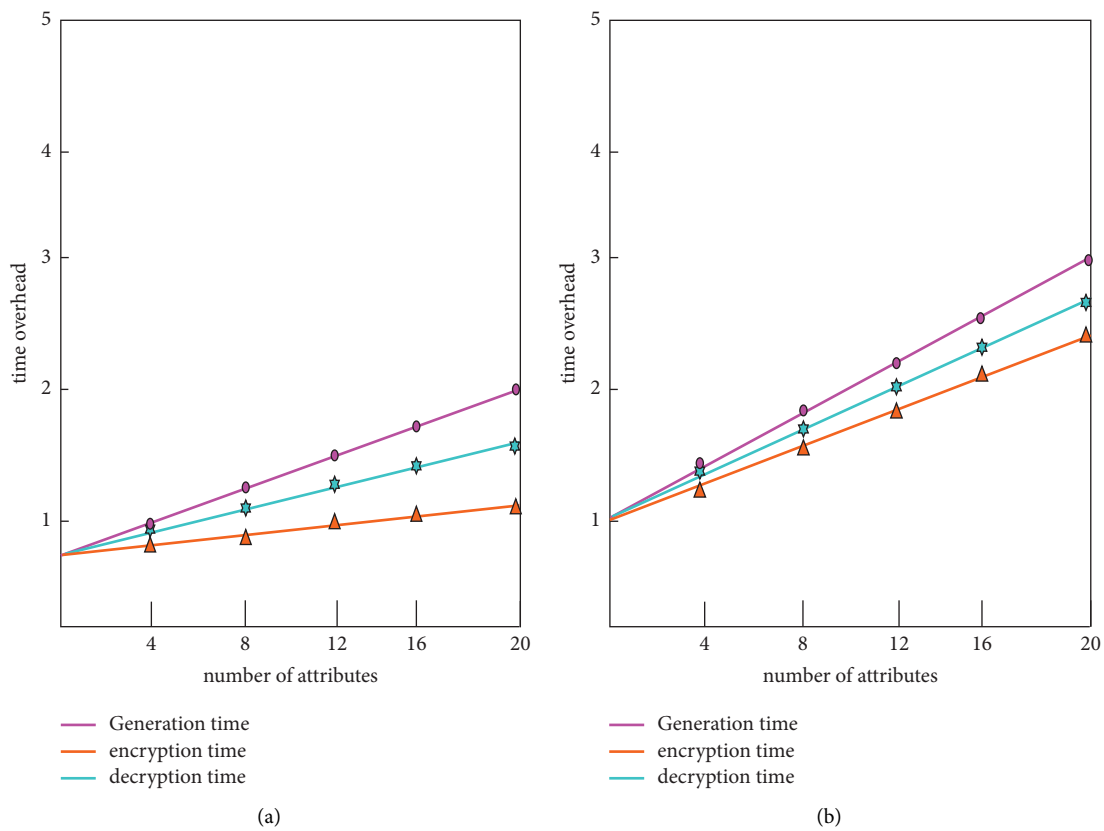

Figure 7: Performance comparison of multiauthority ABE schemes under different files. (a) Performance of multiauthority ABE scheme under 5 MB file. (b) Performance of multiauthority ABE scheme under 10 MB file.

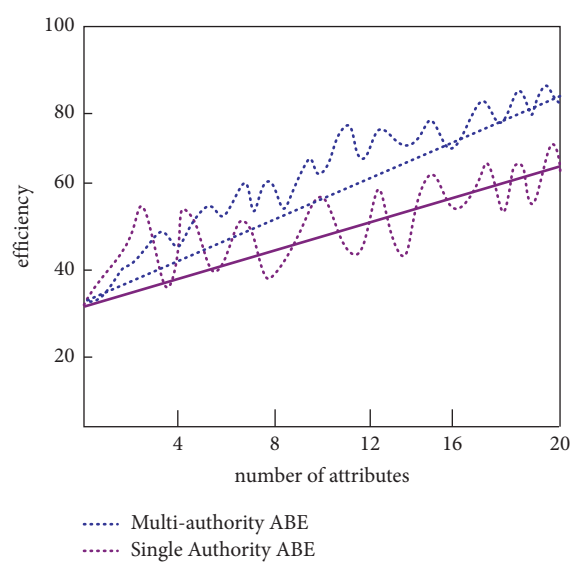

Figure 8: Comparison of decryption efficiency of schemes.

effectiveness. This paper selects 5000 pieces of accounting information data of enterprise A and first compares whether the two algorithms are powerful in accounting information data protection, as shown in Tables 4 and 5.

As shown in Tables 4 and 5, in the information data protection of the single-authority ABE scheme in enterprise A, the confidentiality, reliability, integrity, and validity of the data are the highest at 54%, 55%, 63%, and 58%, respectively.

Table 4: Information and data protection of the single-authority ABE scheme in the enterprise.

Test data	Confidentiality (%)	Reliability (%)	Integrity (%)	Validity (%)
1000	54	55	63	58
2000	53	54	62	55
3000	52	50	60	50
4000	48	46	61	47
5000	46	45	59	46

Table 5: Information and data protection of multiauthority ABE schemes in enterprises.

Test data	Confidentiality (%)	Reliability (%)	Integrity (%)	Validity (%)
1000	79	82	77	75
2000	80	83	79	78
3000	82	85	81	83
4000	84	87	82	85
5000	86	89	85	87

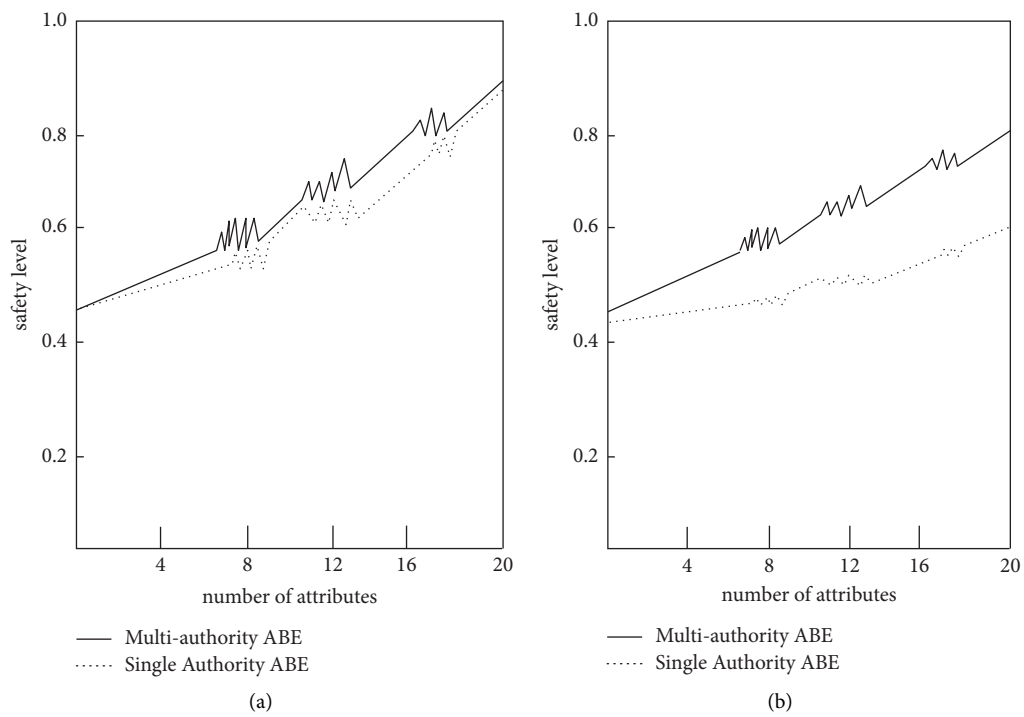

Figure 9: The security index before and after the attack of the two schemes. (a) The security index of the two schemes before the attack. (b) The security index of the two schemes after the attack.

The lowest are 46%, 45%, 59%, and 46%, respectively, and with the increase of information data to be protected, its protection function is getting worse and worse. The confidentiality, reliability, integrity, and effectiveness of the multiauthority ABE scheme in enterprise information data protection are 86%, 89%, 85%, and 87%, respectively. The lowest are 79%, 82%, 77%, and 75%, respectively. With the increase of information data to be protected, its protection function is not only better than that of the single-authority ABE scheme but also the security function is getting stronger.

In order to verify that the security performance of the multiauthority ABE scheme is higher, this paper compares and analyzes the security performance of the single-authority ABE scheme. The two algorithms are encrypted, and then attacked by attack software, and the security index before and after the attack is compared, as shown in Figure 9.

As shown in Figure 9, the security index of the two schemes before the attack is not very different, but after the attack, the security index of the single-authority ABE scheme decreases significantly. However, the security index of the multiauthority ABE scheme has not changed much. It shows that the security index of the multiauthority ABE scheme is more stable. Although the scheme proposed in this paper can improve the efficiency of key generation, encryption, and decryption, the public parameters and master key of the algorithm will increase linearly with the increase of attribute

sets. Therefore, the algorithm proposed in this paper can only be used in the case where the attribute set is small.

5. Conclusions

With the development of network informatization, the problem of accounting information security is becoming more and more serious. Once the accounting information is leaked, it will cause irreversible losses to the enterprise. This paper first analyzed the security problems in the current accounting information and then described the attribute encryption algorithm. Firstly, the algorithm proposed in the basic text of attribute encryption was introduced, and the shortcomings of the single-authority ABE scheme were put forward, thus the multiauthority ABE scheme was described. It was applied to the solution of the accounting information security problem. In order to prove that the proposed scheme was more secure, this paper compared it with the single-authority ABE scheme in various aspects in the experimental part and conducted experiments in terms of time overhead, algorithm efficiency and security performance, respectively. Finally, it is concluded that the proposed scheme has less time overhead, higher algorithm efficiency, and stronger security performance than the single-authority ABE scheme. Therefore, it can be applied to the protection of accounting information data. However, the algorithm proposed in this paper is implemented under the random oracle model, and the scope of application of the algorithm proposed in this paper is very limited, so the data obtained will have certain differences. It will be very meaningful work to construct more attribute encryption schemes with ciphertext strategies in the future.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

A Personalized Learning Path for French Study in Colleges Based on a Big Data Knowledge Map

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The education industry is gradually improving with the rapid development of information technology. The learners use networks and computers to alter the traditional instructional framework based on educational information technology and achieve personalized learning. This teaching method emphasizes each learner's identity and autonomy. However, due to the huge number of learning resources available on the Internet, students lack relevant courses, clear learning tasks, and the connection between various knowledge points, resulting in an unsatisfactory effect on the learning process. Knowledge maps for different learner types are created using historical learners' conceptual knowledge and the segmentation and correlation technique of big data knowledge maps. Using a big data method in this process will automatically generate a set of weak conceptual learning pathways. For this problem, in the era of big data, people put forward the concept of knowledge map and used the algorithm based on the big data knowledge map to study the personalized learning path for college French. The content, structure, and relationship of college French knowledge points can be accurately expressed using this method, which is preferred by college administrators and teachers. This paper aims to investigate the personalized learning path for college French using a big data knowledge map, starting with the characteristics of a college French field of study. This study provides technical support in the establishment of a big data knowledge map based on a learning path recommendation framework. So, after the performance of several commonly used learning path recommendation algorithms, three French students have been selected at random for learning path planning. The results show that personalized learning path planning can be realized based on a knowledge map pre-repair relationship and objective attributes. In the analysis, not only the proposed technique is compared with the conventional optimization approach, but also a comparison study on the benefits of several learning effect prediction models is also performed. The results of this study suggest that this algorithm has a high learning efficiency and that the effective implementation of recommendations produced using our proposed strategy has a significant advantage.

1. Introduction

Education is the process of memorizing information in the human memory for later use in presenting important information or a part of a mental process to fully comprehend everything. The process of acquiring knowledge and skills that can be used to improve consciousness and intelligence is referred to as learning. Learning must be beneficial, pertinent, purposeful, and cumulative and carried out at the appropriate stages to be effective and successful [1]. The feedback learning is one of the significant learning behaviors produced by the learner's e-learning process. The historical response records can be used to determine the learner's conceptual knowledge, and knowledge gaps in the learning process can be precisely identified. A student's understanding of a subject may be lacking if, for comparison purposes, their past response archives reveal a higher exercise error rate for that concept. Because ideas are interdependent, a learning path must be planned to ensure that the learner fully understands the deficient concepts [2]. When performing activities, learners have more difficulties comprehending their conceptual knowledge and making judgments about the efficacy of their operations. Additionally, they could have a hard time analyzing and

assimilating important and targeted concepts. The learner's response data may thus be utilized to automatically determine the connections between ideas, identify weak concepts, and provide individualized learning path assistance in real-world environments [3]. It can enable the students to bridge gaps in knowledge and perhaps grow into important competence in difficult concepts. The basis for the recommended path is built by automatically identifying challenging topics based on learner reaction data and providing future students with a successful introduction to the same concepts, to determine when concepts interact with one another to create tailored weak conceptual learning pathways for the targeted learners and to produce the intended learning outcome [4]. According to the following previous work on personalizing learning path, we build a personalized learning path for college French based on a big data knowledge map using the genetic algorithm.

A large number of them are now based on the previously established knowledge base, which, while occasionally useful, did not fully contribute to each learner's unique knowledge level. To address these issues, Liu proposed a knowledge structure improvement framework of learning approaches. It approaches the path recommendation procedure as a probabilistic decision-making method, keeping in view all personal variables of the learners and using the knowledge base as a framework. This demonstrates that when the learning pathway was designed, the standard learners were assumed to have completed the material, but this was not the case. Most students struggle to comprehend the material they have just learned [5]. Cai developed a knowledge mapping and reinforcement learning-based technique for designing learning paths. The algorithm can effectively predict students' learning progress, model learners' knowledge levels over time, and define students' learning conceptual frameworks [6]. Zhu proposed using long-term and short-term virtual memory (LSTM) to resolve this issue and select a unique learning path from among the suggested solutions. The use of genetic algorithms to design learning paths is one of the most exciting areas of research right now. An improved genetic algorithm based on the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is used in order to facilitate the search for the nearly perfect learning route. TOPSIS, which is analogous to the perfect solution, is utilized to find the roughly optimal learning path solution [7]. The problem of establishing a learning path is described as a multiobjective optimization statement. The features of teaching and learning resources are used to generate a learner-centered knowledge map using a genetic algorithm, and a linear learning sequence is formed from the conceptual model using a traversal algorithm [8].

This study aims to create an algorithm that can automatically generate individualized learning paths based on the learners' current learning stages. Similar to the previous analysis, this one analyzes and comprehends behaviors as important factors in determining the knowledge levels of learners. This research is so much more comprehensive than the previous research, which required teachers to manually evaluate the difficulties in the knowledge points. The complexity of knowledge points for larger classes was automatically determined in this study using an information processing platform. This strategy reduces stress and time spent by instructors with the knowledge map learning resources on the Internet [2]. Personalized learning has become widely used in the field of learning due to the rapid development of the Internet, network technology, and computers in recent years, enabling people to share network learning resources [9]. However, there are a massive number of data learning resources on the Internet, and there are issues with lost knowledge and knowledge overload. The emergence of artificial intelligence technology effectively improves the way learners obtain learning resources, but learners are still unable to quickly obtain a huge number of knowledge points in the network resource environment. When college students study French, they are faced with the problem that numerous teaching resources on the network cannot be effectively used. The knowledge map algorithm solves this problem by combining a knowledge map and a personalized learning path. College students can fully grasp each knowledge point in the French personalized learning process and develop a personalized learning path for college French based on a big data knowledge map. Firstly, based on the entity recognition and the link of the knowledge map, the knowledge map between entities and relationships is established, and the map database is used to store and realize data visualization [10, 11]. The personalized learning path model is then built based on the learning path recommendation algorithm to determine the importance of each knowledge point in the knowledge map, allowing the importance of each knowledge point to be evaluated.

The main innovations in the research process of this paper are the following:

(i) This paper focuses on the analysis of the basic concept, storage mode, and basic architecture of the knowledge map algorithm

(ii) We build a personalized learning path for college French based on a big data knowledge map through text similarity calculation and establish a personalized learning path model

(iii) Using the personalized learning path model, college French students are randomly selected to test the learning path planning results, which are added to the prerequisite relationship map and objective

(iv) College students' attributes to personalized learning path planning based on a big data knowledge map can obtain the best personalized learning path and high learning efficiency

The remaining sections of the paper are organized as follows: Section 2 presents related work of the paper; Section 3 presents knowledge mapping algorithms for large data; Section 4 presents the personalized learning path for university French based on big data mapping; Section 5 presents the analysis of the application results of personalized learning path for college French; and finally, Section 6 concludes the research work.

2. Related Work

Due to the rapid development of network technology, e-learning resources will continue to iterate and be updated. Currently, recommending the best learning paths to students is the future development trend in e-education. At the same time, more and more experts at home and abroad are beginning to study personalized learning based on a knowledge map [12]. Wan et al. represent the data acquisition layer, the information visualization layer, the behavior layer, and the knowledge ontology layer, and then combine the layers to form a knowledge map learning model [13]. Golpardaz et al. proposed the conditional random field (CRF) model, which is the most typical statistical model for entity recognition and can transform entity recognition problems into sequence annotation problems [14]. LV produces a knowledge map of the medical field by statistically analyzing knowledge data in the field of medical education in order to increase students' enthusiasm for learning medical knowledge [15]. Lissa et al., the authors of this study, use the concept of a "knowledge map" in traditional education to express knowledge in the form of a map and display knowledge intuitively and powerfully to improve students' learning efficiency [16]. Tu used scientific knowledge in the knowledge map to show the relationship between various knowledge points in the way of the map. So, the students can visualize the difficulty of different knowledge points on the map, clearly understand the weaknesses of mastering knowledge, and better deal with problems [17]. Zhang and Ma proposed to establish an educational knowledge Atlas system based on a knowledge map in order to display educational knowledge in the form of a map [18]. Bazhukova and Afonina pointed out that the essence of applying a knowledge map to the field of education is to clarify the relationship between knowledge points and form a complete knowledge map [19]. Mohsin et al. use an ant colony algorithm to optimize the learning path and formulate the best algorithm to adapt to learning [20]. Saito and Watanobe enhanced learning path recommendation with a collaborative recommendation mechanism and used this new method in learning path recommendation [21]. Wang et al. used the experimental method to validate knowledge point ranking and selection. They arranged the knowledge points from the learning path based on the knowledge structure in the knowledge map and the reference index [22]. Zhang and Ye initiated with different learner styles and analyzed the similarity between different learners using data from the learning-style scale. It first creates a swarm intelligence learning recommendation model and then employs the improved ant colony algorithm to add the parameters that influence the learning style, because learners can present a common learning path and achieve their goals [23]. Zou, addressing the situation of the learners' questions, then marked the nodes and convoluted the questions with the classification map. It produces the learning path using the Prim minimum spanning tree algorithm and modifies it based on the current learning situation [24]. Aladwan suggested first to designing the learner model, then mining the learners' preferences in the association rules, obtaining the corresponding interactive data and learning results, and eventually having to feed the data into the ant colony algorithm to complete the path recommendation [25].

3. Knowledge Mapping Algorithms for Large Data

3.1. Knowledge Map Algorithmic Concepts. The technology of knowledge mapping covers two parts, namely, the construction of knowledge mapping and the application technology. At present, the main goal is to transform the knowledge that can be understood and calculated by computers on the Internet to form the knowledge that can be understood by people. Therefore, there is an urgent need to build a knowledge map for different industries because different industries require different data integration capabilities for vertical industries [26]. In recent years, knowledge mapping has played an advantage in organizing and displaying knowledge, starting from the field of education, to establish the ideal effect of the personalized learning path for college French based on big data knowledge. This paper develops a personalized learning path based on each student's learning speed, interest, and goal by analyzing knowledge maps and data from college students' French learning behaviors.

An entity is an important unit in the knowledge map, and the essence of entity recognition is named entity recognition in text. The purpose of entity link is to deal with the problem of diversity and ambiguity in entities. If the meaning of MAC is different in different fields, "MAC" has recently introduced a red slogan. In this case, the entity link system should correspond to the "MAC" mentioned in the corresponding text, not the three-tier architecture of MAC in the computer field. Because an object in a large amount of data can be expressed in many different ways, the complexity of large data is very high in the analysis of large amounts of text. So, it is necessary to identify entities and links first to reduce information overload. The technical architecture of knowledge mapping is depicted in Figure 1.

3.2. Knowledge Map Storage. At present, there are two methods for storing knowledge maps containing relational databases and graph databases. However, the amount of data continues to grow as information technology advances, and relational databases cause data redundancy, prompting some people to use graph databases [27]. A graph database is a new NoSQL database that uses a computer graph theory, which analyzes the internal relationships of data more intuitively and efficiently. Compared with relational databases, graph databases are suitable for the storage of this knowledge map. Most data types are semistructured or structured, and graphic databases store data information in a graph-structured sort of way. Users require a significant amount of time and effort to process data, but they will also easily find, modify, add, and delete data. The graph database can be used if the three attributes of nature, concept, and development in educational knowledge points are assumed. These relationships are directional and can be represented in a simple

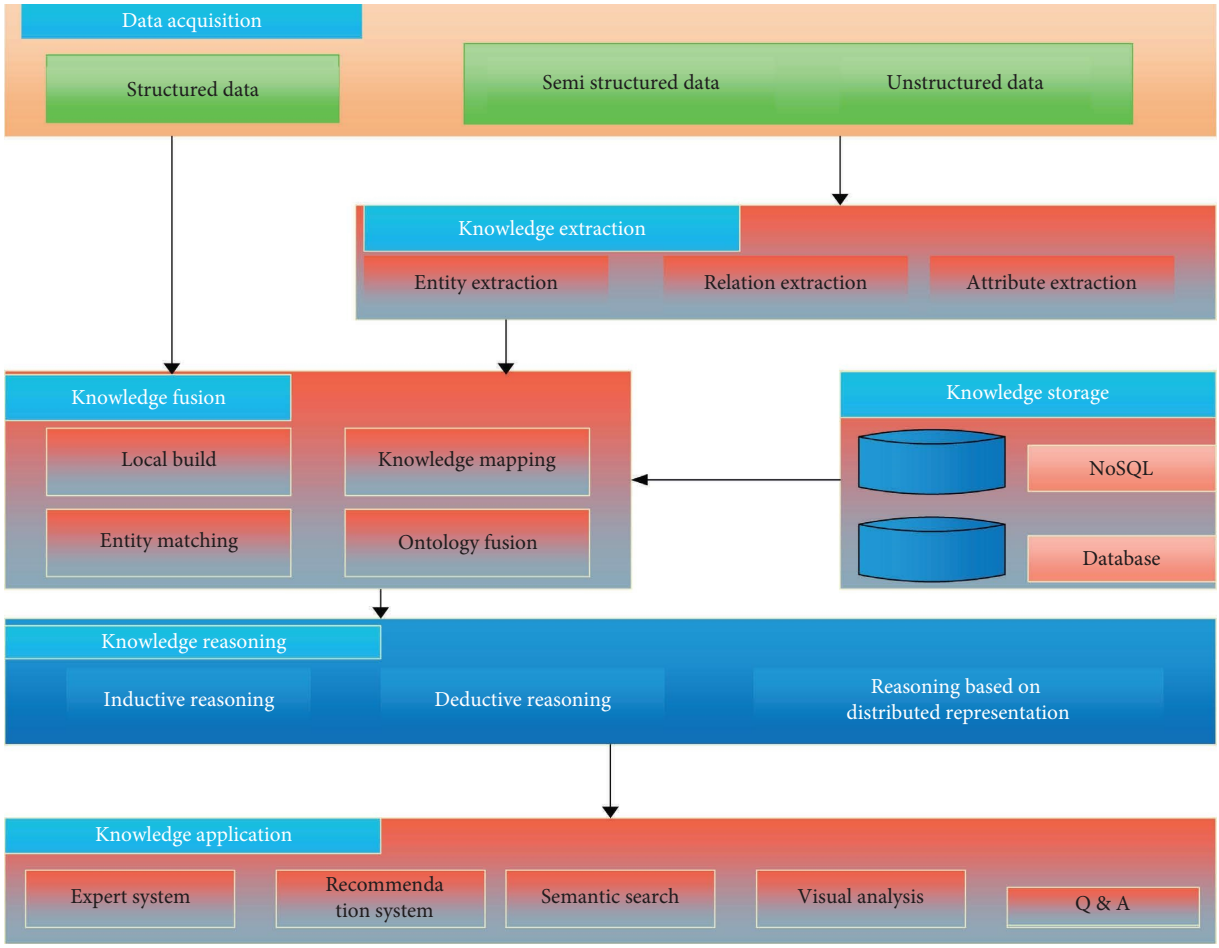

Figure 1: Knowledge map technology architecture.

form to show the connections among the knowledge points. As shown in Figure 2, graphic databases enable complex relationships between entities to be processed effectively.

This paper chooses the Neo4j diagram database and saves the data in the network instead of the traditional local database. The following are the significant advantages of the diagram database over the traditional database:

Step 1: Neo4j is highly compatible and supports popular programming languages such as Ruby and Python

Step 2: The Cypher database query language corresponds to the majority of people's thinking modes

Step 3: Neo4j processes data more quickly and has a very simple storage structure

Step 4: Using the import tool, it can import relational and entity data at the same time, as well as support large-volume data storage with less latency and significant real-time performance

Step 5: Data display page operation is simple

3.3. Text Similarity Calculation. In the personalized learning path for college French based on a big data map, more algorithms are used for similarity calculation, which is also a basic technology in natural language processing (NLP). This paper calculates the similarity between different points of knowledge in college French courses, builds the connection between them based on the results of text similarity, and promotes the learners to achieve the rapid transfer and mastery of knowledge.

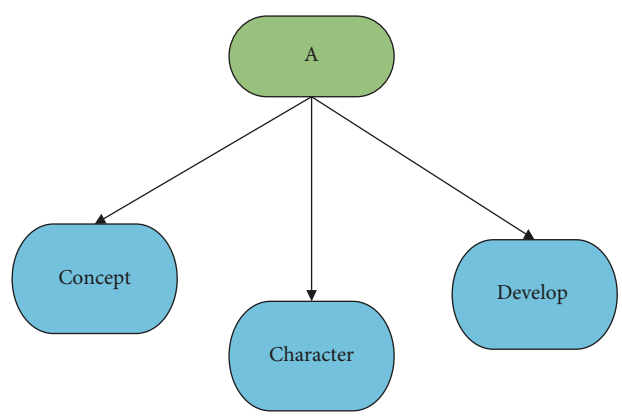

Figure 2: Knowledge map showing knowledge points.

The following details describe several similar calculation methods currently used.

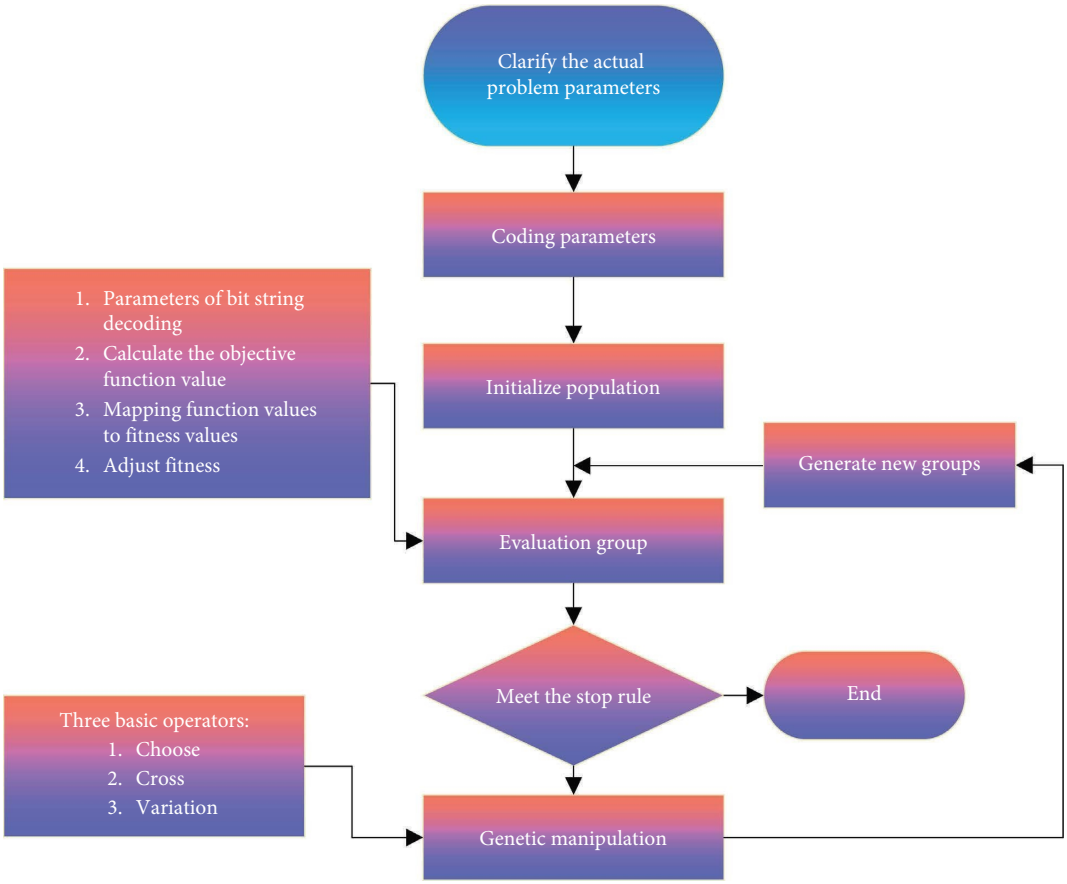

Figure 3: Schematic diagram of genetic algorithm learning path recommendation principles.

3.3.1. Euclidean Distance. When calculating text similarity, Euclidean distance can be used to judge the absolute distance in multidimensional space between two different knowledge points. For example, x represents the word frequency of all words in two texts on knowledge point A. When Y computes the word frequency at knowledge point B, the following results are obtained:

$$sim\ (A, B) = \text{dis}\,(A, B) = \sqrt{\sum_{i=1}^{n} (a_i - b_i)^2}. \quad (1)$$

3.3.2. Cosine Similarity. By calculating the cosine angle through formulas, the similarity of two knowledge points in vector space is judged by the cosine of the angle between two vector points A and B.

$$sim\ (a, b) = \frac{\vec{a} \cdot \vec{b}}{\vec{a} * \vec{b}} = \frac{\sum a_i b_i}{\sqrt{\sum a_i^2}\sqrt{\sum b_i^2}}. \quad (2)$$

3.3.3. Jaccard's Similarity Factor. The Jaccard similarity coefficient compares the similarity of two different knowledge points. Based on the number of knowledge points A and B intersect, the similarity between two knowledge points is calculated by the proportion of knowledge points A and B in the union. The formula is as follows:

$$sim\,(A, B) = \frac{|A\% \cap B|}{|A \cup B|}. \quad (3)$$

4. Personalized Learning Path for University French Based on Big Data Mapping

4.1. Recommendation Algorithm for Learning Paths. This paper studies personalized learning of college French based on a big data knowledge map. Here, two learning path algorithms, namely, the genetic algorithm and the ant colony algorithm, are described in detail.

4.1.1. Genetic Algorithm. The genetic algorithm does not need to compute all possible path solutions, but it needs to select the global optimal solution on the path. In the learning path recommendation algorithm, the genetic algorithm chromosome parameters are coded to find the $F(x)$ fitness value, and then, $P = F(x)\sum F(x)$ is selected randomly. The optimal learning path inheritance process is repeated by crossover, selection, compilation, and so on until the ideal learning path is found. Figure 3 illustrates the genetic algorithm learning path recommendation principles.

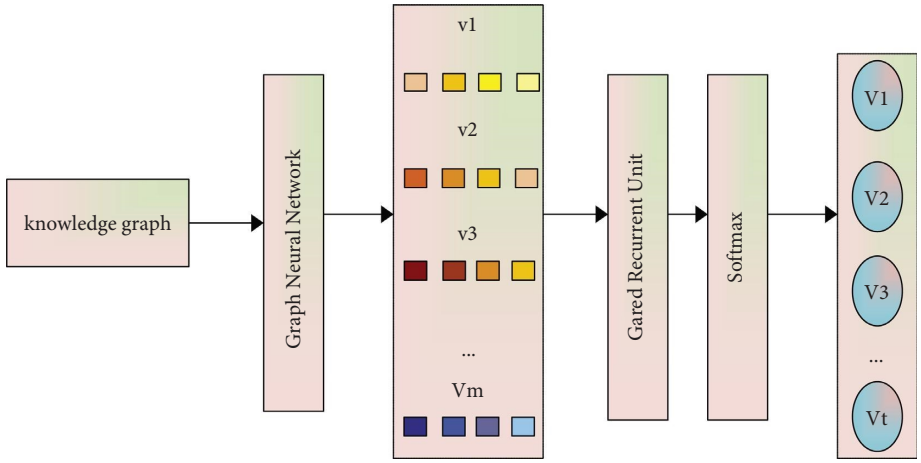

Figure 4: Framework for learning path recommendation based on a knowledge map.

4.1.2. Ant Colony Algorithm. Ant colony algorithm uses the learner's knowledge of French to leave a mark on the network, which is the pheromone to select the later learning path based on the concentration of the pheromone. Therefore, the pheromone is a key formula and path selection probability in the ant colony algorithm:

$$P(i,j) = \frac{[\tau(i,j)]^{\alpha}[\eta(i,j)]^{\beta}}{\sum [\tau(i,j)]^{\alpha}[\eta(i,j)]^{\beta}},$$
$$\tau(j) = (1-p)\cdot\tau(j) + p. \tag{4}$$

Upper form τ enlightens data for the amount of information that a pheromone can provide between Node 1 and other nodes at a given time. η represents the expected value of the transfer node, and p represents the pheromone play factor.

4.2. The Learning Path Recommendation Algorithm Is Based on the Knowledge Map. Based on a knowledge map, a graphical neural network can propagate and aggregate the characteristics of different knowledge points on the knowledge map to form a high-accuracy knowledge point embedded in the vector. The model establishes a reliable sequence based on the knowledge map to infer the importance of knowledge points at all levels. The knowledge point vector matrix is then combined as input to the graphical neural network after the corresponding knowledge point vectors from the knowledge map are first obtained. The selection coefficients related to each node are obtained using the gated graphical neural network. After that, the vector is processed using SoftMax to determine its centrality. A substantial number of datasets are used to test the efficacy of this algorithm after completion, and the probability judgment for choosing the following knowledge point is made. The framework for knowledge map-based learning path recommendation methods is shown in Figure 4.

4.3. Building Personalized Learning Path Model. The essence of planning a personalized learning path for college grammar is to arrange the learning objects in the set of candidate contents in regular order, and then show the sorting structure to the learners for reference. The system automatically recommends the learners listed in front as their next choice. The specific path planning is shown in Figure 5.

As learners enter the system, they can recommend the learning materials they need according to certain rules, or they can send the results of the recommendation to the learners for their own choice. Therefore, the most important thing is to identify the candidate learning set and calculate the weights.

Assuming that T is a coarse-grained learning object with n fine-grained learning objects and M is required to learn, that is, $M_1, M_2, M_3, \ldots, M_n$, the learning object T is defined by the following formula:

$$T = \{M_1, M_2, M_3, \ldots, M_n\}. \tag{5}$$

Based on the knowledge map that there is a preemptive relationship among the learning objects, the preemptive relationship K_{ij} is defined by the following formula:

$$K_{ij} = \begin{cases} 1, & M_j \text{ prefix representing } M_i \text{ learning objects,} \\ 0, & \text{Other cases.} \end{cases} \tag{6}$$

The learner can only acquire and master the learning object after completely grasping all or most of the learning object's prelearning materials. M_i means that the learner has mastered all the prerequisite points on M. Usually, this threshold is set to 0.6, which leads to the definition of Pr_i, the set of prerequisite learning objects in the M_j learning queue, as follows:

$$\mathrm{Pr}_j = \{M_i | \forall \quad M_i \in T, K_{ij} = 1\}. \tag{7}$$

Based on the calculations, the next set C recommended to the learner can be achieved.

$$C = \{M_j | \forall \quad M_j \in T, M_j \in T', \forall \quad Mi \in \mathrm{Pr}_j, P_{M_i} \geq \alpha\}. \tag{8}$$

Topic T' means that the learner has completed all of the learning objectives or that the initial learning is empty. When the learner completes a learning object M, a new M is added to the T'.

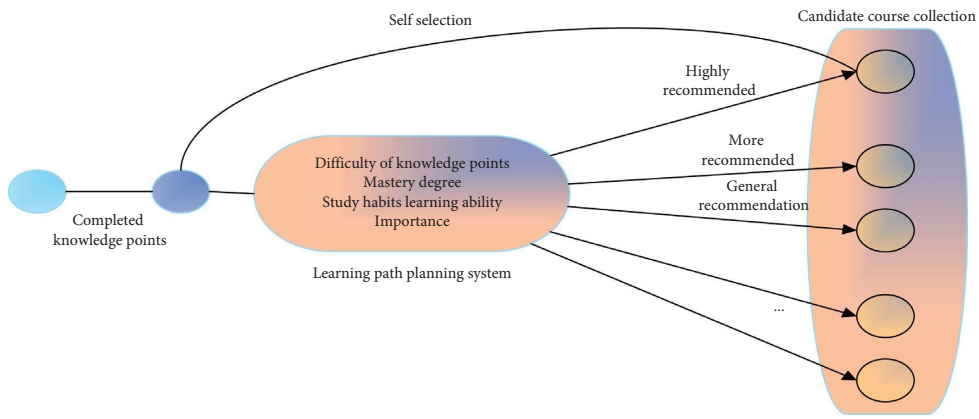

Figure 5: Route planning diagram.

According to the above formulas, the learning objects C are all the prelearning objects that the learners have already mastered. However, some of the learning objects do not meet the learning requirements. They also need to review the prelearning objects further. Here is the formula C for reviewing the set of learning objects:

$$C' = \{M_k | \forall \quad M_j \in T, M_j \in T', \forall \\ M_i \in \mathrm{Pr}_j, M_j \in T', \exists M_k \in \mathrm{Pr}_j, P_{M_k} < \alpha\}. \tag{9}$$

C is the set of candidates learning objects, and C' is the total number of learning objects awaiting review. The learning materials that must be retained after the review are maintained in this set. This algorithm arranges the candidate learning objects in a specified sequence according to predefined rules, after which the learner decides for themselves whether to learn next. The course and knowledge point weights are defined here in terms of different formulas, and the knowledge point weights are defined by these formulas:

$$B_M = \frac{\sum_{i=1}^{m} b_i}{m}, \\ W_M = \frac{e^{-(B_M - 0.5)^2/2} I_M(\overrightarrow{P})\left(1 - e^{-\mathrm{Imp}_M}\right)}{\sqrt{2\pi}\left(1 + \left(1 + e^{-\mathrm{Imp}_M}\right)\right)}. \tag{10}$$

b_i indicates the difficulty of the title i, and B_M indicates the difficulty of M knowledge points. This algorithm calculates the average difficulty of each knowledge point on M. $I_M(\overrightarrow{P})$ denotes the benefits that $\overrightarrow{P}$ learning sequence learners have gained from learning M knowledge points. Im_{PM} represents the importance of M knowledge points. W_M, W_M represents the weight of M knowledge points when planning a route. A high value indicates that this knowledge point is more suitable for the next learner to use as a learning object.

After clarifying that there are no courses to be materialized, one of them is selected for learning. The difference between the points of comparison is that before arranging the French courses, the restriction of the learner is analyzed. The following formula defines the weight W_T of a French course T.

$$W_T = \frac{kI_T}{K}. \tag{11}$$

Top I_T denotes the benefits that learners will receive from the T. French course and K denote the number of students in the broad course that learners will receive from the T. Based on the weight of the course, the number of times a learner in the learning group has studied a course indicates that the learner has earned a high return from learning the course. Therefore, the course in this language will be preferred to other learners.

5. Analysis of the Application Results of Personalized Learning Path for College French

This paper builds a model of personalized learning path for college French based on a big data map because it studies the best personalized learning path for college French. Based on the data from XuetangX dataset, a knowledge map is built for the course of college French. There are 19 nodes, 19 edges, and 70 exercises in this knowledge map. Three of them are randomly selected to plan the personalized learning path for college French using the knowledge map algorithm based on large data, and the three learning paths listed in Table 1 are obtained:

According to the data in Table 1, the order of learning knowledge points of the three students is different. The results of the income obtained from the calculation of the learning knowledge of the three students are also different in that the differences among the three students are not significant even though their initial learning behaviors are different. Firstly, the knowledge sequence is planned from the learner's previous learning behavior. During the planning period, no new learning behavior occurs. As a result, students can only predict the sequence in a fixed learning style when answering questions. Because of data factor interference, no complete knowledge map has been established, the number of trainings is very minor, and the recorded course video is small, making this parameter ineffective.

Table 1: Learning path planning results.

Learner number	48504238	62834945	24850562
Knowledge point sequence	1–9–12–11 –10–14–13 –2–4–3–8 –7–6–5–15 –19–16–18–17	1–9–12–11 –10–14–2–8 –4–3–7–6 –5–13–15 –19–16–17–18	1–2–4–3 –8–7–6–5 –9–12–11–10 –14–13–15–19 –16–18–17

Table 2: Route planning data statistics excluding knowledge point benefit parameters.

Learner number	48504238	62834945	24850562
Knowledge point sequence	1–9–12–11 –10–14–13–2 –8–4–3–7 –6–5–15–19 –16–17–18	1–9–12–11 –10–14–13 –2–8–4–3 –7–6–5–15 –19–16–17–18	1–9–12–11 –10–14–13–2 –8–4–3–7 –6–5–15–1 9–16–17–18

Table 3: Route planning with all parameters removed.

Learner number	48504238	62834945	24850562
Knowledge point sequence	1–15–16–17 –18–19–9–10 –11–12–13–14 –2–3–4–5 –6–7–8	1–15–16–17 –18–19– 9–10 –11–12–13–14 –2–3–4–5 –6–7–8	1–15–16–17 –18–19–9–10 –11–12–13–14 –2–3–4–5 –6–7–8

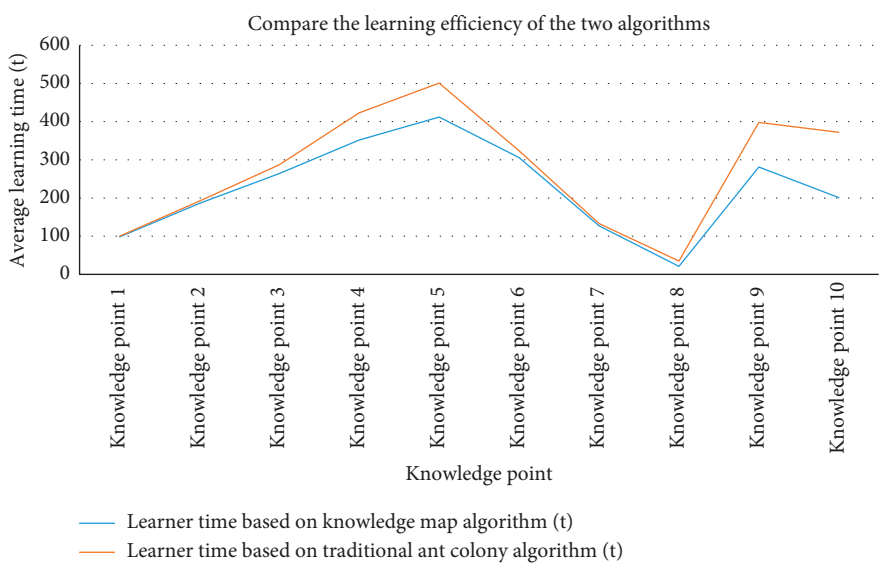

Figure 6: Comparison of learning efficiency between two algorithm learners.

5.1. Analysis of Learning Accuracy. In this study, the accuracy of the personalized learning path for college French based on the big data map is studied. According to the data in Table 1, the recommended accuracy of each learning path is 1.0, 0.947, and 0.842 calculated by substituting it into the formula above, which indicates that the learning planning path has a higher accuracy [28, 29]. Since the current dataset contains a complete French course for the learner, the lists at the time of knowledge point recommendation will cover the learner's learning.

The parameters in the knowledge point model are readjusted here to highlight the personalized learning path, and two additional groups of experiments are added to compare, that is, learning path planning with each parameter excluding the benefit of knowledge points. The results are presented in Tables 2 and 3.

Table 2 shows the corresponding learning path planning without taking into account the benefits from learning knowledge points. The three students get the same learning path planning because knowledge points are of the same

importance and difficulty to the learners and do not show the personalized characteristics of different students. Table 3 is the initial learning path. It does not use the knowledge point parameters mentioned in the paper and does not take into account the prerequisite relationships in the knowledge map. It is the configuration of open knowledge points made during instruction by university professors. From the results of observations, it can be concluded that the only way to plan a path that differs from the initial learning path is to consider the knowledge map's objective attribute and precondition relationship constraints. The learning benefits from each learner can then be added together to create an individual learning path.

5.2. Analysis of Learning Efficiency. When proving the efficiency of this algorithm based on a big data knowledge map, this paper randomly extracts ten knowledge points from French college learners and compares them. The learning efficiency of this algorithm is obtained by individual learning paths based on the ant colony algorithm. The result is shown in Figure 6.

The learning efficiency of the algorithm based on the knowledge map of large data is significantly higher, as shown by the line graph in Figure 6. The individual learning path is then based on the traditional ant colony algorithm, with similar learning efficiency for each knowledge point. This demonstrates that a personalized college French learning path based on a big data map is more efficient, can fully utilize each student's personality, and can improve students' French learning efficiency.

6. Conclusions

The analysis of personalized learning is currently a hot topic in the educational era of big data and the Internet. When big data and the Internet play an important role in educational achievement, system design expands significantly. The explosion of e-learning websites has provided the education sector with a variety of new learning data. As a result, it is possible to identify the learner's knowledge point and mine the implicit relationships between learning. It aims to encourage different types of students to use appropriate teaching methods to maximize their benefits. However, in the era of big data, the rapid increase in data amount makes students unable to find a suitable learning path in the face of vast teaching resources, resulting in low learning efficiency and loss of motivation. This paper takes the personalized learning path for college French as the object and establishes the personalized learning path model for college French based on the big data knowledge map. Based on the knowledge map, it identifies the learning path algorithm in detail and develops the personalized learning path. Three French students from colleges and universities were chosen at random to compare the learning outcomes of various learning paths. According to the findings, the best results for personalized learning paths based on a big data knowledge map are those that can personalize course planning for students. When compared to students who follow a personalized learning path based on the ant colony algorithm, the algorithm mentioned in this paper has a higher learning efficiency. Several large college education datasets can be used to confirm the future, and more in-depth analyses can be performed in combination with learner behavioral aspects such as time spent answering questionnaires and frequency of reminders.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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

Creation of Drama Art Based on Deep Learning and Evolution Strategy

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The rapid development of information technology has promoted the growth of deep learning, artificial intelligence, and big data technology. Nowadays, the artistic form of traditional opera creation is accepted and respected by people—more and more people like the art form. However, the artistic creation of traditional opera needs inspiration. The essence of inspiration creation is to reconstruct its objective structure. The deep learning algorithm's essence is to extract all of the attributes of sample self-learning input data and use them as inspiration for artistic production. First, this paper briefly introduces the deep learning and evolution strategy and uses these algorithms in opera art creation to construct $1 + \lambda$. With the help of this evolutionary algorithm, an optimal solution is obtained through random evolution. The evolution strategy establishes the evolution function matrix. Starting from the situation of students learning opera art, this article examines the process of creating opera art using an in-depth learning and evolution technique. The results show that 96 percent of the students have contact with opera while watching an opera tour. During this, they were not interested in the performance of literary drama in traditional opera. However, it was noticed that they were deeply interested in martial arts, clown performances, and drama stage performances. Finally, the audience group of opera artistic creation is analyzed in the form of opera animation of "A Journey to the West: The Return of the Great Sage." It signifies that the opera's leading audience group is aged 25 to 29. However, they account for only 30 percent.

1. Introduction

Some consider opera outdated, yet it shows no signs of vanishing on the world stage. It continues to draw large crowds. Given its relationship with luxury, one can think of opera tickets as a status symbol. While the urge to rub shoulders with the upper crust may inspire the occasional operagoer, the true motivator for dedicated fans is passion—they do it for love. Some attest to a specific opera's ability to affect them—whether to song or tears—regardless of how many times they have seen it. Drawing on the incisive examination of these acts of love, this paper introduces new ways of thinking about people's relationships to art and demonstrates how, rather than just enriching parts of daily life, art helps us transcend them.

In China, opera culture has been created by accumulating national culture for thousands of years. It fully reflects virtuality, programmability, and comprehensiveness. It is the spiritual carrier of Chinese culture and has very high aesthetic, artistic, research, and educational value [1]. However, in recent years, young people have had an indifferent attitude towards opera art. They are unwilling to inherit and carry out China's opera culture and art. It has resulted in an inability to inherit China's traditional Opera art [2]. To resolve this problem, this paper uses deep learning and evolutionary strategy algorithm to study the artistic creation of traditional opera and analyze the process of artistic creation of traditional opera in China.

This paper also uses BP neural network and deep confidence network in deep learning. They are combined with

an evolutionary algorithm to study the problem of opera art creation. An evolutionary algorithm is an algorithm that imitates biological evolution mechanisms. It uses the concept of biological evolution and variation to modify parameter values and uses iterative evolution to obtain satisfactory results [3]. It can be used as an inspiration for opera art creation [4, 5]. Combining the two algorithms to analyze the process of opera art creation, we can get the relevant opera creation data.

The innovation of this paper is reflected in the following:

(i) It organically combines deep learning and evolution strategy to study drama art creation. It also describes the deep learning algorithm and neural network model to extract the drama art features in the initial model based on the deep learning algorithm, further evaluating the initial model's evolution features and constructing the evolution function matrix [6].

(ii) It completes the drama art creation based on the evolution strategy, using $1+\lambda$. The evolution strategy completes the mutation operation, establishes the artificial evaluation function matrix, and obtains the evolution matrix after training to complete opera art's evolution.

The remaining study paper is structured as follows: related work is explained in Section 2. This is followed by depth information and evolution strategy in Section 3. Section 4 describes the drama art creation based on depth information and evolution strategy. Similarly, Section 5 explains drama art creation analysis based on in-depth learning and evolution strategy. Finally, the conclusion of the study is written in Section 6.

2. Related Work

Opera culture is the main part of China's traditional culture and the most valuable national art. In the recent 20 years, the interaction between opera art, in-depth learning, and evolution strategy has attracted the attention of Chinese and foreign scholars. It has achieved many positive research results [7]. Few scholars have proposed that using opera art's implicit and explicit educational characteristics in college education is conducive to better-completing opera art creation [8]. The study of opera art involves explaining opera knowledge in class, appreciating famous opera masters, telling opera story plots, and analyzing the inner meaning of opera. At the same time, it also involves the compilation of opera literary scripts and the ensemble of musical instruments [9]. It has been pointed out that opera is an elegant art, symbolizing the national spirit. It is an essential form of artistic edification in people's growth. It can alleviate people's pressure on study and work and shape a good personality and character [10]. Therefore, as intangible cultural heritage, it should be protected. Presently, young people are not interested in opera art and culture. It impacts the inheritance of Chinese opera culture. By analyzing the characteristics of opera culture and modern culture and its disadvantages, we can find an ideal way to promote and publicize opera art [11]. Combining film art with traditional opera to develop a unique art form, namely, opera film, it takes rural areas as the central area, adheres to traditional culture, and finds a new channel to publicize and promote opera [12]. Some scholars have also pointed out that China's song art has distinctive characteristics. Traditional opera art has been dramatically affected by the impact of foreign opera art. Colleges and universities innovate teaching methods in opera teaching and integrate folk diet and opera art to generate a variety of opera artworks [13]. Several current Zaju in China endow the leading spirit to the drama, weaken the drama plot and contradiction, fully reflect the style of the times of Zaju, and become a typical representative in the history of Chinese drama [14]. Comparative analysis of opera theory studies the artistic fiction in opera creation, avoids the interference of subjective factors such as the author's voice and consciousness, and improves the quality of opera art creation. At the same time, it integrates the social and cultural customs and mentality into opera creation, so that readers at all levels can understand the significance of communication in opera artworks and jointly promote the rapid development of opera art in the Ming and Qing Dynasties [15].

3. Depth Information and Evolution Strategy

This section explains deep learning in detail to acknowledge its effects on drama art creation. Further, it describes the neural network model, BP network, and deep confidence network. All these algorithms in combination help demonstrate how the in-depth information and evolution strategy can grab viewers' attention towards the drama art creation. The explanation is as follows:

3.1. Deep Learning. In the 1950s, American scholars proposed a deep learning algorithm. It was used to analyze the results obtained in various ways. They proposed two learning modes, that is, deep learning and shallow learning [16]. Deep learning pays attention to stimulating teaching mode during teachers' learning. It does not pay attention to the passive inculcation teaching method of shallow learning. It seeks a learning route to improve students' learning efficiency in the classroom. Figure 1 shows the deep learning route (DELC) [17].

3.2. Neural Network Model. This subsection explains the BP Network and deep confidence network in detail. It can help us signify their importance and role in affecting drama art creation. It also shows how the young generation can be attracted to traditional culture. The explanation is as follows:

3.2.1. BP Network. BP network or backpropagation neural network is a feed-forward neural network. As a widely used learning algorithm, it corrects the connection weights between different layers of neurons in a multilayer network by fully utilizing the error of back-propagation to get the desired target values. There are two different propagation modes in learning backpropagation neural networks. They are as follows:

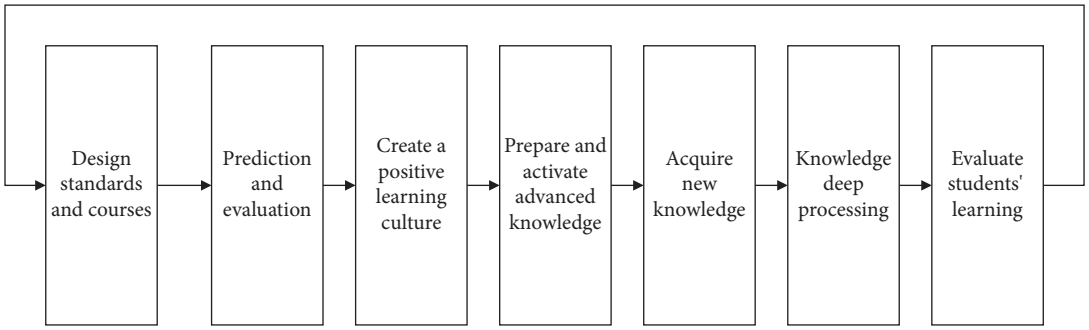

Figure 1: Deep learning route (DELC).

(i) *Forward Propagation Signal*: the data is analyzed and calculated after input samples are processed from the hidden layer. The result is calculated in the output.

(ii) *Error Back Propagation*: if the forward propagation results do not meet the standard requirements, an error higher than a certain threshold shall continue to reverse propagation. It indicates that the expected value is obtained. It transfers errors to each layer of neurons and corrects the network. Cyclic propagation of the two processes continues until the error is lower than the threshold.

Figure 2 is a BP network model in which the input layers are $x_1, x_2, \ldots, x_n$, the output items on the output layer are $y_1, y_2, \ldots, y_m$, and the numbers on the three layers of neurons are i, j, k, connected with the weights of neurons. U denotes the bias of neurons and inputs the sample x to the BP network. The output Y is obtained after analysis and calculation. Assuming y^* denotes the desired target result, the following is the basic formula for calculation error:

$$E(w,b) = \frac{1}{2}\sum_k \left(y_i - y^*{}_i\right)^2. \tag{1}$$

The neural network's bias value and weight parameters shall be corrected to minimize the error function. The network parameters shall be adjusted based on the gradient downregulation method. The following are the weight correction values of the i-th neural network and the j-th output neuron.

$$\Delta w(i,j) = -\eta \frac{\partial E(w,b)}{\partial w(i,j)}. \tag{2}$$

The following formula is obtained based on $\text{net}_j = \sum_i w_{ij} y_i$:

$$\frac{\partial \text{net}_j}{\partial w_{ij}} = \frac{\partial}{\partial w_{ij}} \sum_j w_{ij} y_i. \tag{3}$$

Hypothetical retransfer $\delta_j = (E_p/\text{net}_j)$ is obtained as follows:

$$\delta_i = y_i(1 - y_i) \sum_j \delta_j w_{ij}. \tag{4}$$

Therefore, the following weight correction values can be obtained:

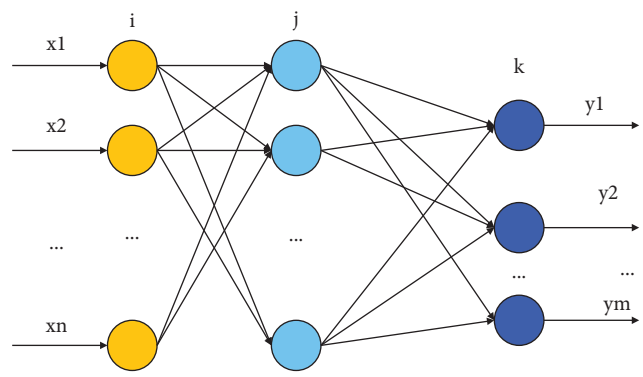

Figure 2: BP network structure diagram.

$$\Delta w_{ij} = \eta \delta_i y_i. \tag{5}$$

Presently, BP neural network is becoming more and more mature. The main advantage is that the network structure is very flexible and can independently adjust the number of network layers and the number of nodes on each layer. The disadvantage is that the convergence speed is too slow. If the training speed is set fast, it shall fall to a local minimum. On the contrary, it shall lead to different results and more layers, resulting in error dispersion. Therefore, it is always recommended to set the network structure according to the accumulated experience.

3.2.2. Deep Confidence Network. If there are many layers of the BP neural network, it shall lead to the problem of error dispersion. When adjusting the bottom parameters, the effect shall be reduced. It shall not be easy to extract data features accurately. A deep confidence network (DBN) is proposed to better deal with this problem. The network is formed by stacking multilayer restrictive Boltzmann machines that belong to the probability generation model. The data in the model is divided into label data and observation data, which need to be evaluated. In addition, the discrimination model only needs to evaluate label data. After comparing the backpropagation network with the deep confidence network, the latter has a better training effect and network hierarchy.

Boltzmann machines (RBMs) belong to stochastic neural networks. Restricted Boltzmann machines remove the

connections between neurons based on Boltzmann machines. In short, RBMs is a bipartite graph. RBMs comprise a hidden layer (h) and a visual layer (v). If the value on the network parameter is non-zero, that is, 1, it indicates the connection between layers. There is no connection between different nodes in the layer. $p(v, h)$ meets the requirements of Borel probability distribution; that is, the bipartite graph is RBMs.

There is an apparent RBMs structure in the single-layer Boltzmann machine. The structure should connect h hidden layer and explicit layer as different nodes are in an independent relationship. w represents the connection weight, w_{ij} is the connection weight between v_i hidden layer neurons, h_i HJ hidden layer neurons, b_i Bi is the bias of v_i hidden layer neurons, and a_i is the bias of h_i hidden layer neurons.

RBMs is the energy model, and the joint configuration energy is calculated by using the following formula:

$$E(v, h, \theta) = -\sum_{ij} w_{ij} v_i h_j - \sum_i b_i v_i - \sum_j a_j h_j. \tag{6}$$

The above equation e is the model parameter $\theta = \{w, a, b\}$. Different neurons are independent in the layer, as follows:

$$P(h|v) = \prod_j P(h_i|v). \tag{7}$$

Using the decomposition factor to find the probability result that the j-th node is 1 or 0,

$$P\left(h_j = 1|v\right) = \frac{1}{1 + \exp\left(-\sum_i w_{ij} v_i - a_j\right)}. \tag{8}$$

This definition meets the independent distribution sample set requirements $D = \{v^{(n)}\}$, and the value of n is 1,2, N. Here, the maximum likelihood estimation value must be calculated to obtain the required e parameters:

$$L(\theta) = \frac{1}{N} \sum_{n=1}^{N} \log P_\theta\left(v^{(n)}\right) - \frac{\lambda}{N} \|w\|^2{}_F. \tag{9}$$

Calculate the derivative of the maximum likelihood estimate and obtain the w value corresponding to the maximum L as follows:

$$\frac{\partial L(\theta)}{\partial w_{ij}} = Ep\left[v_i h_j\right] - Ep_\theta\left[v_i h_j\right] - \frac{2\lambda}{N} w_{ij}. \tag{10}$$

4. Creation of Drama Art Based on In-Depth Learning and Evolution Strategy

This section demonstrates the research process based on depth information and evolution strategy, art creation based on evolution strategy, and evolution function matrix. Together, they can help us clarify the creations of drama art based on in-depth information. The explanation is as follows:

4.1. Research Process Based on Depth Information and Evolution Strategy. This paper studies opera art in combination with in-depth learning and evolution strategy. It proposes the process of in-depth learning and evolution to jointly explore the inspiration of opera art creation [18]. The following is the process of creation of drama art based on in-depth learning and evolution strategy:

Step 1: Extract the features on the initial model based on the deep learning algorithm;

Step 2: Evaluate the characteristics of the initial model manually after evolution to form a test and a training set;

Step 3: The fitness value obtained by training the evolution function matrix is similar to the evaluation model;

Step 4: Evolution model: use fitness value to approximate, simulate, and evaluate the evaluation model to meet the requirements. After completing this operation, the results are returned to step 2;

Step 5: Results are obtained.

Figure 3 shows the research process of creating drama art based on in-depth learning and evolution strategy. The initialization model is extracted using a deep learning algorithm in the above process. Afterwards, the extracted model features are evolved to form a new model. The train model evolution function matrix is used to extract the fitness evaluation. Finally, the fitness model is used to guide the continuous improvement of the model, and drama art creation products are obtained in the process.

4.2. Creation of Art Based on Evolution Strategy. An evolutionary algorithm is the central part of evolutionary strategy. It uses the concept of biological compilation to modify the parameter values randomly. Iterative evolution produces a desirable result. The evolutionary algorithm mixed with the interactive process underpins the interactive evolution approach. It is used to increase people's subjective consciousness in order to regulate the evolution direction, minimize the quantity of algorithm parameter training, and make the algorithm converge faster [19]. The interactive evolution strategy in the field of image processing achieves ideal results. It has the ability of subjective judgment and searches for a solution. Also, the obtained solution is more practical. This paper uses $1 + \lambda$ which is the basic principle of this strategy. It is used to initialize the parameters to obtain the ideal individual. The iteration needs to be suspended if it is consistent with the conditions. On the contrary, the best individual shall mutate to generate a new individual into a new generation. Finally, the best individual is obtained.

As adopted in this paper, $1 + \lambda$, during the implementation of the evolution strategy, various mutation algorithms or evolution methods are used, such as uniform mutation, differential mutation, and Gaussian mutation.

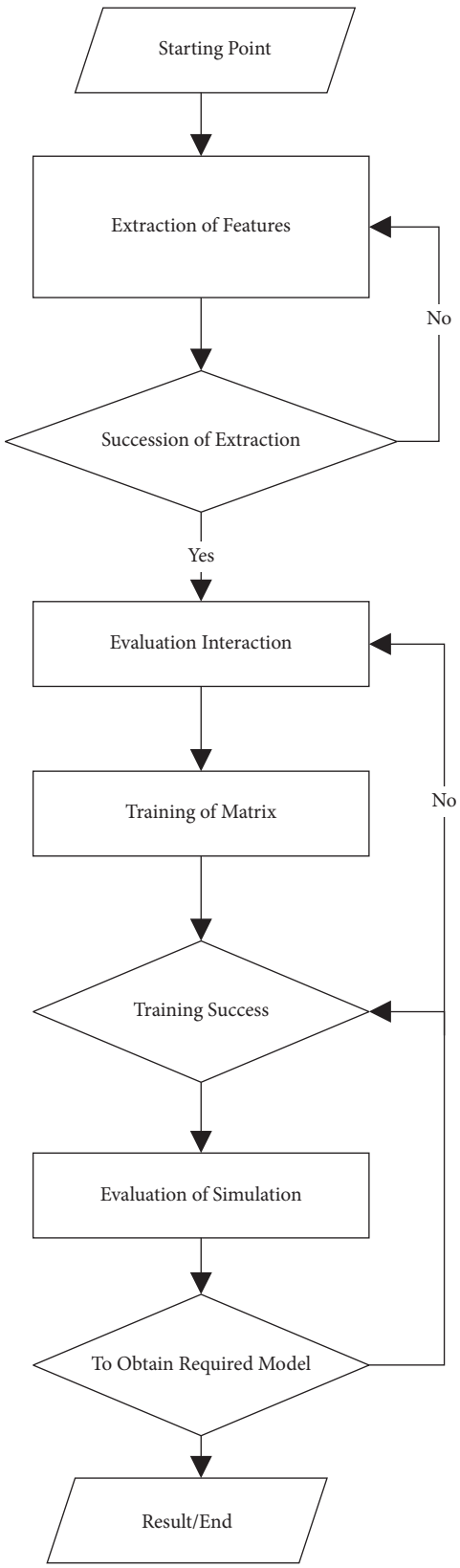

Figure 3: Flowchart of the overall approach.

Each mutation algorithm has different effects in each scene. Therefore, corresponding experiments must be used to complete the mutation operation in different stages. The most suitable algorithm is obtained based on the experimental results. The following are the basic principles of three mutation algorithms:

4.2.1. Differential Variation. If F is the scaling factor, the value of the i-th individual of generation m is represented by p_i^m, the i-th individual of generation $m-1$ is represented by p_i^{m-1}, the value of the j-th individual of generation $m-1$ is represented by p_j^{m-1}, the z-th individual of generation $m-1$ is represented by p_z^{m-1}, and both z and j are randomly selected values. Use the following formula to calculate p_i^m:

$$p^m{}_i = p^{m-1}{}_i + F * \left(p^{m-1}{}_j - p^{m-1}{}_z\right). \tag{11}$$

4.2.2. Gaussian Variation. In the evolutionary algorithm, $L(|n-\mu|/\sigma < 3) = 0.9975$, $y_{\max} = n+3$, $y_{\min} = n-3$. If C is the detection condition, d is the constraint condition, and y is the median value of Gaussian variation:

$$y = y_{\min} + 1.0 * \left(y_{\max} - y_{\min}\right) * \operatorname{rand}(0,1). \tag{12}$$

The following are constraints:

$$\begin{aligned} c &= \frac{1}{\sqrt[2]{2\pi}} * e^{(y-y\min)^2/2}, \\ d &= \frac{1}{\sqrt[2]{2\pi}} * \operatorname{rand}(0,1). \end{aligned} \tag{13}$$

Supposing that d is greater than c, the y value needs to be detected again. On the contrary, the output result of Gaussian variation is that g is equal to y.

4.2.3. Uniform Variation. Only a positive integer in an interval can be obtained in the uniform mutation evolutionary algorithm, affected by the particularity of mutation demand. Therefore, the algorithm is relatively simple, and the output result of y is represented by the following:

$$y = \operatorname{rand}(\,)\%n, \tag{14}$$

$1+\lambda$ The control parameters used in the strategy are mutation probability and population size, which must be determined manually. Generally speaking, the population size of the evolutionary strategy is smaller than that of other evolutionary algorithms.

4.3. Evolution Function Matrix. During the research of this paper, we need to analyze the experimental cases. The samples generated by manual evaluation have high investment. We need to use many samples in the experiment to reduce the number of manual evaluations. Therefore, we design the simulated artificial evaluation evolution function matrix, train the matrix to obtain the fitness approximate to the artificial evaluation model, and use the model to simulate

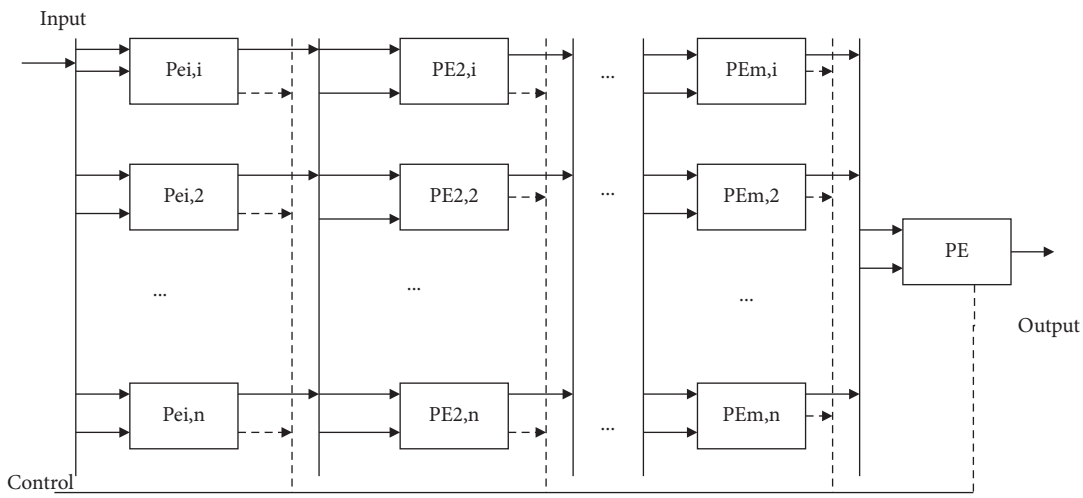

Figure 4: Function matrix of evolution.

Table 1: Processing unit operation.

Number	Function	Number	Function
0	x	4	Min (x, y)
1	$(x+y)>>1$	5	$X<<1$
2	$(x+y+1)>>1$	6	X or y
3	Max (x, y)	7	y

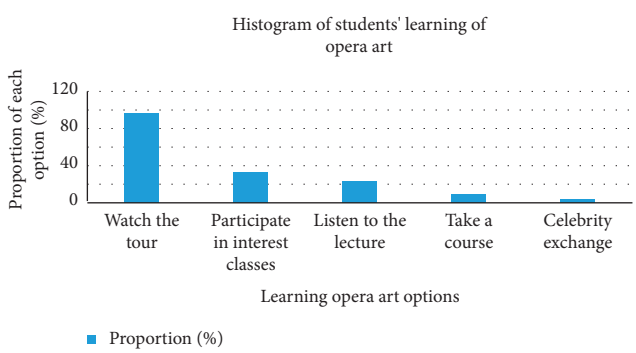

Figure 5: Histogram of students' learning of opera art.

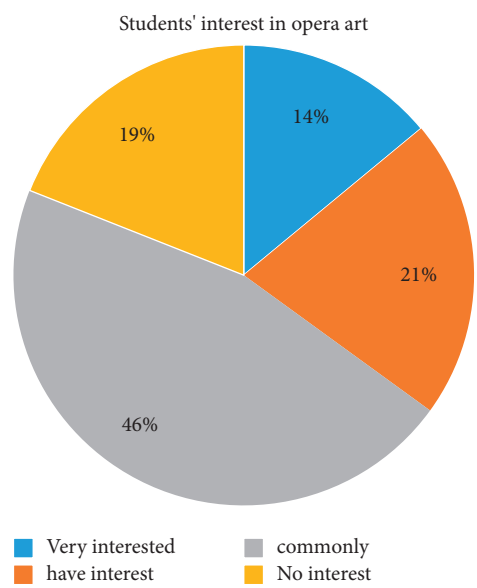

Figure 6: Students' interest in opera art.

the interactive evaluation process to improve the algorithm's operation efficiency [20].

It is imperative to construct the fitness approximation model. We should use the evolution matrix to learn the subjective evaluation characteristics and construct the evolution function matrix, that is, the process of training the evolution matrix. As shown in Figure 4, the evolution function matrix has 6 columns and 55 rows. There is only one processing unit in the last column. Vector is the input. Here, the data comes from the characteristics of an evolutionary neural network. Output is the score of the evolution function matrix after manual calculation and simulation, and control is the operation code of the control evolution function matrix.

The first five columns in the evolution function matrix have 55 matrix cells. The operation code on each matrix cell has an operation function, two operands, and four connection parameters. They correspond to the two offsets and weights of the two operands. The operands are obtained by random formula. The two dimensions on the input vector can be randomly obtained as operands. The operation functions of the processing unit are listed in Table 1. After selecting one of them randomly, if the output of the j-th matrix cell on the column i is represented by O_{ij} and f is the operation function, and the output of the matrix cell of two operands is randomly selected in the column $i-1$, represented by x_1 and x_2, then the two weights are w_1 and w_2, the two offsets are b_1 and b_2, the two connection parameters

Table 2: Students' behavior in watching drama tour.

Activity link	Activity form	Subject participation status	Participation
Introduction to opera culture	Drama Teacher's explanation	(1) Listen carefully	(1) Most
Pera classic performance	Theatrical performance	(1) Watch Carefully (2) Chat (3) Play	(1) Nearly half (1/2) (2) A small part (1/3) (3) Less part (1/5)
	Martial arts or clown show	(1) Watch Carefully (2) Chat (3) Play	(1) Most (2) A small part (1/6) (3) Very few parts
Unique performance of traditional opera	Stage performance	(1) Watch Carefully (2) Chat (3) Play	(1) Most (90%) (2) Very few parts

corresponding to the x_1 operand are b_1 and w_1, and the two connection parameters of the x_2 operand are w_2 and b_2. The following is the calculation formula:

$$O_{ij} = f\left(w_1 x_1 + b_1, w_2 x_2 + b_2\right). \tag{15}$$

One dimension of the output vector on the front row matrix cell is the value obtained on O_{ij}, and the output vector on this column is the input vector on the next column $i+1$ matrix cell until the end of this operation, and the output of the fifth column matrix.

In this paper, Gaussian variation $(1+\lambda)$ is used. The evolution strategy trains the evolution function matrix and constructs an evaluation model with similar fitness.

5. Drama Art Creation Analysis Based on In-Depth Learning and Evolution Strategy

This section sheds light on the analysis of students' learning and audience analysis of opera art. The analysis of students learning opera art examines 1000 test subjects who were listening to the opera art, watching tours, and lectures. The results show how many of them were interested in drama art. Similarly, the audience interest was also analyzed. The explanation is as follows:

5.1. Students' Learning Analysis of Opera Art. This paper adopts deep learning and evolution strategy analysis to study opera art creation. The algorithm is used to construct the evolution function matrix of opera art creation in order to select the content conducive to opera art creation. The experimental method is used to analyze the situation of students' learning opera art and investigate the form, interest, and degree of students' participation in opera art creation in a local school.

Several options are set during the experiment. It mainly includes watching tours, participating in interest classes, listening to lectures, participating in drama courses, and having famous experts' exchanges. During the experiment, 1000 students from a school were selected, of which 96% said they had watched the tour, 32.5% participated in the interest class, 22.8% said they had heard opera lectures, 9.5% said they had participated in opera courses before, and 3.7% had communicated with opera celebrities. The details are shown in the histogram in Figure 5.

After further investigation of the students' interest in learning opera art, it was revealed that 14% of these students are very interested in opera art, 21% are interested, 46% are generally interested in opera art, and 19% are not in opera art. The details are shown in Figure 6.

According to the statistical data in Figures 5 and 6, students are mainly exposed to opera by watching the tour and less systematically studying opera art. Only 9.5% and 90.5% of students have not systematically studied opera art. During the study period, the drama tour activities carried out by a school were sorted out, and the student behaviors in each activity link were classified and counted. It is shown in Table 2.

According to the survey data in Table 2 above, most students could carefully listen to opera teachers' explanations—about half of the students who carefully watch opera on the stage literary drama performance. Similarly, one-third of the students chat, and one-fifth of the students play. Most students observed it when entering the opera, martial arts, or clown performance. When it comes to opera stage performance, about 90% of the students observe it, and a few students are found chatting. The data shows that martial arts, clown performances, and stage performances in traditional Chinese opera attract students' attention and arouse their interest in traditional Chinese opera art.

5.2. Audience Analysis of Opera Art. Opera art creation is combined with animation to launch opera works with more innovative effects and meet the aesthetic requirements of modern people [21]. When analyzing the audience of opera art, this paper selects "Journey to the West: The Return of the Great Sage" as an example to illustrate that this work is a typical representative of the combination of opera and animation. It can fully display the characteristics of opera art and animation. The analysis results of the opera audience are shown in Figure 7.

Figure 7 shows that the degree of interest of those under 19 years old in the return of the great sage of journey to the west is 3.1%, and the audience aged 20–24 is 26.1%. 30% of those aged 25–29, 17.2% of those aged 30–34, 9.8% of those aged 35–39, and 13.8% of those aged over 40. Opera is a unique culture in China. It enhances the sense of national cultural identity. The animation form of traditional opera breaks the traditional opera viewing form in order to attract

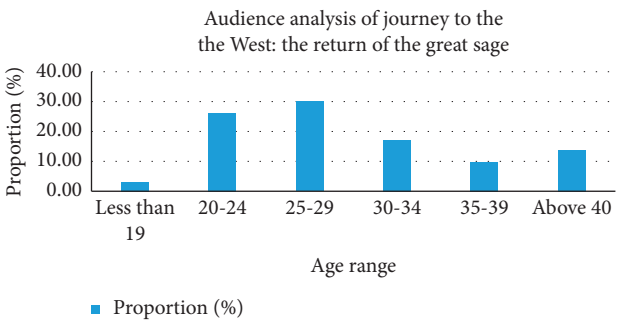

Figure 7: Audience analysis of Journey to the West: The Return of the Great Sage.

audiences of all ages and indirectly cultivate a large number of audiences who love opera culture. People with more contact with opera forms shall also have a strong interest in opera. It is conducive to the inheritance and development of opera culture.

6. Conclusion

In essence, the principal mission of modern music education and music educators is to arouse our young generation's interest and passion for the art of music via the application of the most sophisticated current achievements in music education, instilling in the youth a high spiritual and aesthetic educational formation. In the case of traditional heritage, opera art is a special "civilized memory" and "cultural heritage" in China. It has a history of thousands of years and has a profound cultural inheritance. Foreign culture has a significant impact on Chinese opera art due to the rapid development of globalization. It makes opera art face a huge development dilemma and survival crisis. Based on the in-depth learning and evolution strategy, this paper studies the artistic creation of opera, establishes the evolution function model of artistic creation, and analyzes the primary forms of students' contact with opera. Among these, 96 students learned the artistic charm of opera on the opera tour. Finally, to analyze the drama art creation audience group, we choose the drama animation form of "Journey to the West: The Return of the Great Sage." The results show that the leading audience group for drama is between 25 and 29, which accounts for 30%. It indicates that the drama audience group is getting the younger generation's attention after its creation.

Data Availability

The datasets used or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest for the publication of this paper.

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Research Article

Evaluating Teaching Quality in Colleges and Universities of Public Art Education Using the AHP Fuzzy Comprehensive Method

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The effectiveness of classroom teaching has emerged as the determining factor in whether a school will endure as higher education in China develops. Currently, all schools and institutions have established public art education classes that offer art education to students who do not study art. With the establishment of public art education, students of other subjects can learn art, film and television, music, calligraphy, dance, and drama and master basic practical skills that fundamentally improve their aesthetic capacity and qualities that promote the emergence of morality, intelligence, physique, and glamour among college students. However, colleges and universities should assess the teaching abilities of teachers after establishing public art education programs and then improve their own teaching abilities by fully altering the public art education model in accordance with the results of the teaching evaluation quality score. This study establishes a method for evaluating the effectiveness of teaching in public art education courses at colleges and institutions. The fuzzy comprehensive is based on the analytic hierarchy process (AHP). The system for evaluating the quality of teaching is established, which builds the teacher's teaching evaluation factor set, decides how much weight each teacher's teaching quality evaluation factor should have, establishes the teaching quality evaluation grade, and decides the comprehensive teaching quality evaluation method. The teaching quality evaluation is finally computed using the fuzzy comprehensive evaluation formula and the AHP approach in accordance with the evaluation results provided by five different types of experts. The results indicate that department leaders awarded teachers a 94.11 rating for their ability to teach.

1. Introduction

Education is the process of facilitating learning, which includes the acquisition of knowledge, skills, values, morals, beliefs, habits, and personal growth. Education is the development of knowledge and change in a logical, optimistic, and polite manner, with the premise that everyone should be able to engage in life. Education should place a strong emphasis on developing and directing students' artistic education, in addition to developing and directing students personal abilities. Every individual needs a comprehensive education that is both competitive and rich in the arts. Students that would not ordinarily be interested in classwork may benefit from the integration of art with other subjects. Learning through the arts promotes the growth of innovative problem-solving abilities. Teaching through the arts can help students understand complex ideas by graphically presenting them. Training in the arts would help children improve their motor, verbal, social, judgment, risk-taking, and creative abilities.

Assessment of public art education programs at colleges and universities is now a significant metric for assessing and comparing instructors' competence and effectiveness as teachers. To ensure high teaching quality, the evaluation of teaching quality can determine whether teachers follow the outline, better understand and adjust teachers' teaching processes and team outcomes, fully grasp teachers' overall quality, and examine the challenges and drawbacks of college teachers' training [1].

In this study, the AHP fuzzy comprehensive assessment approach is used to evaluate the standard of instruction for college and university public art education programs. This method establishes a comprehensive evaluation teaching quality system based on the AHP by combining the AHP and

fuzzy comprehensive evaluation methods. A fuzzy comprehensive assessment model based on this method is created, and it is utilized to assess college professors' teaching abilities and provide a complete score. This model can effectively save human resources in colleges and universities, improve the level of teaching management, store a large amount of data, share resources, diversify evaluation indicators, and reduce the inconsistency between the evaluation results and the situation caused by the fuzziness and diversity of teaching quality [2].

The following are the novelties of this study:

(1) The algorithms required for this research are introduced, including the analytic AHP. The operational process and fuzzy comprehensive evaluation technique of the algorithm are analyzed to build a comprehensive evaluation model [3].

(2) Using the AHP fuzzy comprehensive evaluation method, the teaching effectiveness assessment model of public art education programs at colleges and universities is built, and the strength of the teachers' teaching effectiveness assessment factors is determined by building the factor set of teachers' teaching quality evaluation.

The remainder of the article's components is as follows: The related work is covered in Section 2. Section 3 of the article contains the AHP-based fuzzy comprehensive evaluation method, which is further divided into three sections. Section 4 is composed of the Building Fuzzy Comprehensive Evaluation Model for Teaching Quality of Public Art Education in Higher Institutions, which is further divided into three sections. Section 5 is composed of the evaluation results for public art education teaching quality at colleges and universities, which is further divided into two sections, and finally, the concluding portion of the proposed strategy is presented in Section 6.

2. Related Work

In the 1980s, in the area of evaluating education, the United States proposed a novel assessment concept, which focuses on the key decision-making process. At that time, Britain placed a comparable focus on assessing teachers' instruction and developed an AHP-based standard [4]. Deng *X* et al. created a model for evaluating the teaching quality of colleges based on the upgraded back propagation (BP) neural network approach, which can be used to gauge student interest in the subject matter and improve the course [5]. Guo *J* et al. employed big data analysis to solve challenges in the English instruction of college students. It can be seen from the built-in model that the college English teaching quality track can better control students' learning accounts. By creating a huge data analysis model for college students, this study can produce more accurate results for our English teaching quality assessment [6]. Sun *Q* presented a knowledge recommendation system and an enhanced Relevance Vector Machine (RVM) algorithm-based evaluation model for classroom instruction quality. The input data are taken to judge the reliability and accuracy of the results for verification of the model. The results show that RVM can be better applied in the construction of classroom teaching [7]. Lu C. et al. presented the Radial basis function (RBF) neural network teaching quality assessment approach based on genetic algorithm optimization for teaching improvement evaluation to address the declining accuracy of English interpretation. The RBF neural network teaching assessment model is built using the principal component analysis approach, which is used to determine the indicators for evaluating teaching quality [8]. Wang *Y* et al. studied the issues related to determining the effectiveness of physical education instruction in colleges and institutions. A multi-attribute fuzzy assessment model of physical education teaching quality in colleges and universities was developed to address this issue, and it has since become a crucial foundation for addressing issues with physical education teaching and systemic issues [9]. Lin *M* et al., to reform the teaching ability of art courses in higher vocational colleges, built an evaluation teaching index system and a reform ability evaluation model that can successfully enhance the quality of art education in colleges and universities [10]. Ayaneh et al. emphasized that a key instrument for evaluating teaching performance and accountability is teacher effectiveness evaluation. The thinking structure of the teacher evaluation scale is presented, and a range of goodness of fit indexes are used to gauge judgment, for evaluating the efficacy of the higher education school effect scale and the student evaluation structure [11]. Chaeruman et al. focused on the study and development of teaching system models with the aim of creating the Instructional System Design (ISD) model to create curriculum guidelines for instructors using a range of formative data-collection technologies and the ISD model to assess the quality of the curriculum [12].

3. AHP-Based Fuzzy Comprehension

Based on the AHP, a fuzzy comprehensive assessment technique is presented in this section. This section is divided into the following three sections.

3.1. Analytic Hierarchy Process (AHP). The AHP is a decision analysis method combining quantitative and qualitative analysis. This method can break down difficult and time-consuming issues into several distinct variables and levels as well as quantify and model a complex system decision idea, as shown in Figure 1 [13]. Through comparison and calculation of different factors, the weights of various schemes can be obtained in which the ideal scheme can be selected.

According to the AHP methodology, the scheme is evaluated based on its sub-objectives, objectives, departments, constraints and other aspects of the hierarchical structure. The judgment matrix is then obtained using two pairs of methods, and the eigenvector component corresponding to the judgment matrix's maximum eigenvalue is selected as the coefficient to determine the scheme's weight.

3.2. Fuzzy Comprehensive Evaluation Method. When evaluating a system, the multi-index element set U can be used to represent it if the system being evaluated contains evaluation indexes. V comment components can be used to evaluate

comments on several levels. If the evaluation is weighted, a fuzzy vector with a weight distribution should be created. The fuzzy comprehensive evaluation approach works as follows:

(1) Building a U indicator element set in the evaluation system

The system's contents for various assessment indicators together comprise aspects at several levels. The element set is represented by $U = \{u_1, u_2, \ldots, u_m\}$. The evaluation elements in the system are $u_i = (i = 1, 2, \ldots, m)$.

(2) Building a set of V comments

A range of potential result items are included in the comment set's constituent parts. There is a single comment set, regardless of how many result components are categorized. The aspects of the evaluation index should be examined before creating the evaluation grade. If $V = \{v_1, v_2, \ldots, v_n\}$ is the comment set, $v_i = (i = 1, 2, \ldots, n)$ represents comments of different grades.

(3) Defining weight set A

Each U element is reasonably assigned the corresponding weight $a_i = (i = 1, \ldots, m)$, which can reflect the importance of different elements. At the same time, $a_i \geq 0$, $\sum_{i=1}^{m} a_i = 1$, all weights are constructed into a fuzzy set, and $A = \{a_1, u_2, \ldots, u_m\}$ is called the weight set.

(4) Constructing an R-fuzzy relation matrix

The evaluated system is quantified by the elements in $u_i = (i = 1, 2, \ldots, n)$, and a sample table indicating the grade and indicators of the evaluation system is sent to each evaluation team. After recycling, the number of rating comments r_{ij} corresponding to different evaluation indicators can be obtained. The calculation formula is as follows:

$$r_{ij} = \frac{\text{Number of evaluators selecting the } j-\text{th evaluation in the } i-\text{th index}}{\text{Total number of judges}}. \tag{1}$$

The R-fuzzy connection matrix is created using (1), r_{ij} is the u_i system evaluation index to evaluate the degree of membership of the V_j evaluation set, and (2) is the fuzzy relationship matrix:

$$R = \begin{pmatrix} R(u_1) \\ R(u_2) \\ \cdots \\ R(u_n) \end{pmatrix} = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix}. \tag{2}$$

(5) Selection of the evaluation model

Equation (3) is a weighted average model:

$$\begin{aligned} bj &= \sum_{i=1}^{m} a_i \cdot r_{ij} \, (j = 1, 2, \ldots, n) = A \cdot R, \\ B &= (b_1, b_2, \ldots, b_n). \end{aligned} \tag{3}$$

(6) Computing comprehensive evaluation

Commentary judgments can be quantitatively expressed by assigning rank components. Assuming that the E-matrix is obtained after assignment, $E = (p_1, p_2, \ldots, p_n)^T$ can obtain the comprehensive evaluation result of $S = B \cdot E$, which is the comprehensive evaluation score of the evaluated system [14].

3.3. Comprehensive Fuzzy System for Evaluating Teaching Quality Based on the AHP. This study develops an AHP-based fuzzy comprehensive teaching quality rating system using browser/server (B/S) architecture. Users can use the Internet to assess the effectiveness of teaching at any time and from anywhere due to the employment of this architecture within Internet and campus network [15]. The evaluation system consists of three levels, each of which is broken down into three layers under the application logic: data access, business logic, and presentation. During the design and development of the system, some auxiliary methods and types are needed, such as transaction class and database access class [16]. When creating the system architecture, each module is divided into a separate portion to increase the usage rate across modules. Views and data tables in the database are the objects in the fuzzy comprehensive teaching evaluation system based on the AHP, which can be transferred between different layers. Methods and object entities can be efficiently separated throughout the design phase, as a public entity class module, and this entity has been abstracted [17]. The system's overall structure is shown in Figure 2.

4. Building a Fuzzy Comprehensive Evaluation Model for Teaching Quality of Public Art Education in Higher Institutions

The process for the model establishment of fuzzy comprehensive evaluation for the teaching of public art education quality in higher education is divided into three sections, which are as follows.

4.1. Establishing a Teacher Teaching Quality Evaluation Factor Set. The creation of the teacher's teaching evaluation factor set is the first step in the process of developing a teaching quality assessment model for public art instruction at colleges and universities built on the AHP fuzzy comprehensive evaluation approach. The hierarchical structure of the model

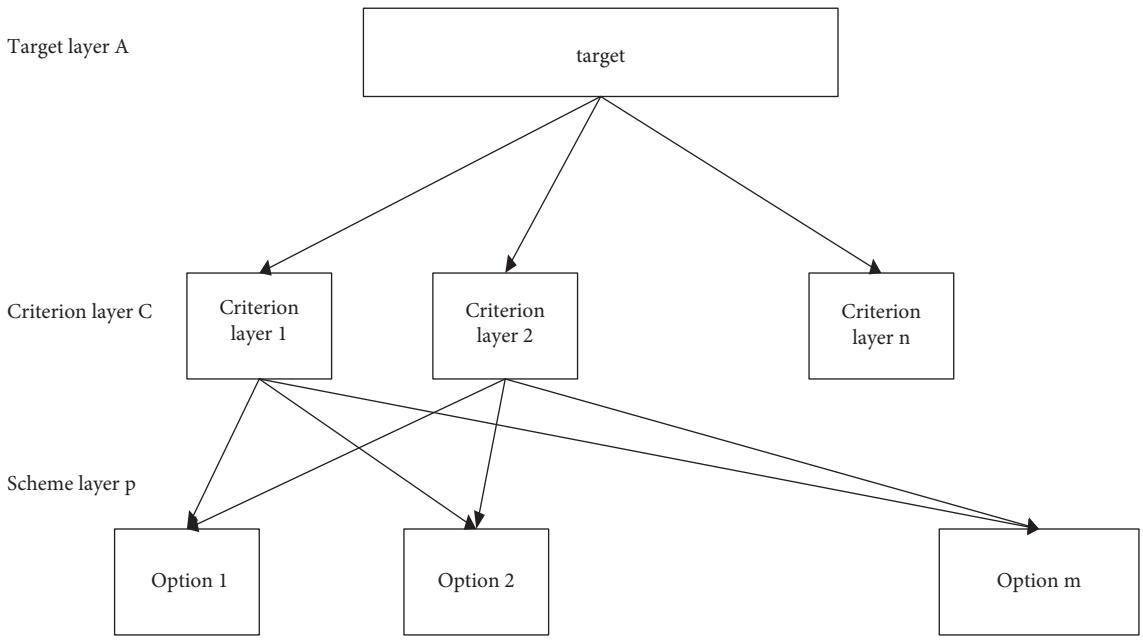

Figure 1: The structure of AHP.

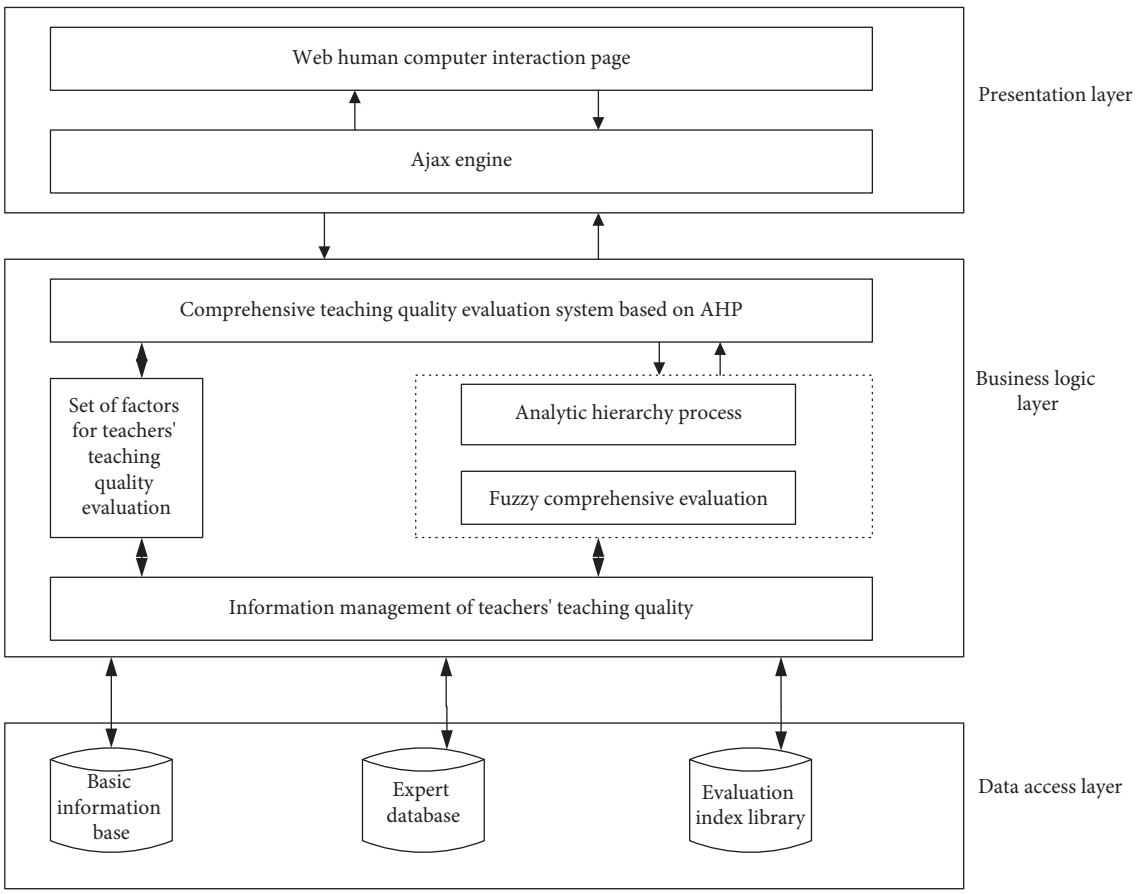

Figure 2: AHP-based system architecture for comprehensive teaching effectiveness evaluation.

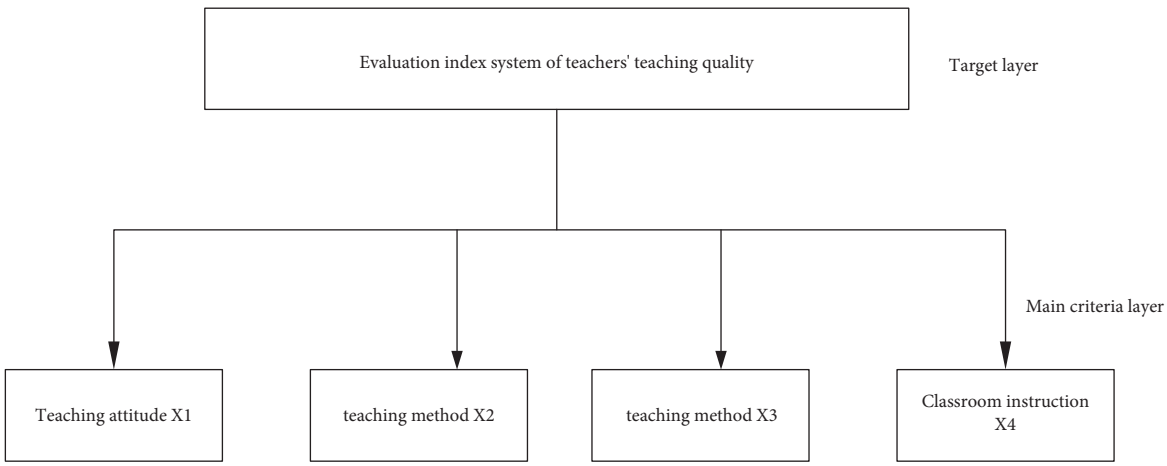

Figure 3: Assessment of teaching effectiveness index for teachers.

Table 1: relative significance.

Scale	Meaning
1	The importance of comparing X_i and X_j is the same
3	The former is slightly more important when comparing X_i and X_j
5	Comparing X_i and X_j, the former is significant than the latter
7	Comparing X_i and X_j, the former is significant than the latter
9	Comparing X_i and X_j, the former is significant than the latter
2,4,6,8	Median value of parallel judgments 1–3, 3–5, 5–7, 7–9
Reciprocal	The comparison judgment between X_i and X_j is represented by X_{ij}, and X_{ji} is the comparison judgment between X_j and $X_iX_{ji} = 1/X_{ij}$

is shown in Figure 3; $X = X_1, X_2, X_3, X_4$ is the set of evaluation factors defined for the alignment side layer $X_k = X_{k1}, X_{k2}, \ldots, X_{knk}$, in which k is 1, 2, 3, and 4. The factor of class i on the criteria level is represented by nk, among which there are n single factors. Figure 3 shows the assessment index system of teaching effectiveness for teachers.

4.2. Weighting the Evaluation Criteria for Teachers' Teaching Quality. The weighting factor should be calculated in accordance with the relationship between the relative weights of the various elements affecting the teaching quality evaluation since each component's value in a teacher's evaluation of their teaching effectiveness varies. The weight set of various aspects in the primary and sub-criteria layers is clarified using the AHP approach. The principal techniques are as follows [18].

4.2.1. Constructing a Judgment Matrix. In the 9-level scaling approach, 1, 2, 3, 4, 5, 6, 7, 8, and 9 are used to indicate the relevance of the results for various components in the pairwise comparison factor set. For example, X_1 is the teaching attitude, X_2 is the teaching content, X_{12} is the comparison result of the importance of the teaching attitude compared with the teaching content, and X_{21} is the importance of the teaching content compared with the teaching attitude. Therefore, different evaluation factors can be compared to establish a comparison matrix. The following is the A judgment matrix:

$$A = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1n} \\ x_{21} & x_{22} & \ldots & x_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ x_{n1} & x_{n2} & \ldots & x_{nn} \end{bmatrix}. \quad (4)$$

The importance of the judgment matrix X_i compared with X_j is expressed by X_{ij}, and the expert evaluation team calculates the importance values of elements in different criteria layers.

The experts compare the various criteria level factors of the same type for teaching quality evaluation at the same criteria level and measure and judge them in accordance with Table 1, based on how many different teaching quality assessment elements make up the total evaluation factors.

A fourth-order judgment matrix is constructed into a primary criterion layer according to the construction of the judgment matrix, which is represented by (5). There are four different types of univariate sets in the criteria layer, which

can construct four different orders expressed by the following formulas:

$$A = \begin{bmatrix} 1 & \frac{1}{3} & \frac{1}{4} & 2 \\ 3 & 1 & \frac{1}{2} & 7 \\ 4 & 2 & 1 & 8 \\ \frac{1}{2} & \frac{1}{7} & \frac{1}{8} & 1 \end{bmatrix}. \tag{5}$$

$$A_1 = \begin{bmatrix} 1 & 4 & 3 & 3 & 2 \\ \frac{1}{4} & 1 & 1 & \frac{1}{2} & \frac{1}{3} \\ \frac{1}{3} & 1 & 1 & \frac{1}{2} & \frac{1}{3} \\ \frac{1}{3} & 2 & 2 & 1 & \frac{1}{2} \\ \frac{1}{2} & 3 & 3 & 2 & 1 \end{bmatrix},$$

$$A_2 = \begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{3} & 2 & 1 \\ 2 & 1 & \frac{1}{2} & 5 & 4 \\ 3 & 2 & 1 & \frac{1}{2} & 3 \\ \frac{1}{2} & \frac{1}{5} & 2 & 1 & \frac{1}{2} \\ 1 & \frac{1}{4} & \frac{1}{3} & 2 & 1 \end{bmatrix},$$

$$A_3 = \begin{bmatrix} 1 & 4 & 1 & 4 & 2 & 4 & 2 & 1 \\ \frac{1}{4} & 1 & \frac{1}{3} & 1 & \frac{1}{3} & 1 & \frac{1}{2} & \frac{1}{3} \\ 1 & 3 & 3 & 4 & 1 & 4 & 2 & 1 \\ \frac{1}{4} & 1 & \frac{1}{4} & 1 & \frac{1}{3} & 1 & \frac{1}{2} & \frac{1}{3} \\ \frac{1}{2} & 3 & 1 & 3 & 1 & 3 & 2 & 1 \\ \frac{1}{4} & 1 & \frac{1}{4} & 1 & \frac{1}{3} & 1 & \frac{1}{2} & \frac{1}{3} \\ \frac{1}{2} & 2 & \frac{1}{2} & 2 & \frac{1}{3} & 1 & 2 & 2 \\ 3 & 1 & 1 & 2 & 3 & 1 & 3 & 1 \end{bmatrix},$$

$$A_4 = \begin{bmatrix} \frac{1}{2} & 1 & 1 & \frac{1}{4} \\ 1 & 2 & \frac{1}{2} & 3 \\ 2 & 4 & 5 & 1 \\ \frac{1}{3} & 1 & 1 & \frac{1}{5} \end{bmatrix}. \tag{6}$$

Each row vector of the A judgment matrix is calculated. If $\overline{W} = [\overline{w_1}, \overline{w_2} \ldots \overline{w_n}]$ vector is obtained, then (7) can be obtained by standardizing it and the approximation $\widetilde{W}_i = [\widetilde{w}_1, \widetilde{w}_2 \ldots \widetilde{w}_n]$ of W can be obtained. $A\widetilde{W} = \lambda_{\max}\widetilde{W}$ and (8) can be obtained.

$$\widetilde{W}_i = \frac{\overline{w_i}}{\sum_{j=1}^{n} \overline{W}_j}. \tag{7}$$

$$\lambda_{\max} \approx \frac{1/n \sum_{i=1}^{n} (AW)_i}{\widetilde{w}_i}. \tag{8}$$

The A judgment matrix is calculated as follows:

$$\begin{aligned} W &= [\,0.892 \;\; 2.883 \;\; 0.76 \;\; 0.452\,], \\ \widetilde{W} &= [\,0.113 \;\; 0.354 \;\; 0.482 \;\; 0.057\,], \\ \lambda_{\max} &\approx 4.032. \end{aligned} \tag{9}$$

The values of $A1$, $A2$, $A3$, and $A4$ judgment matrices and the values of k are 1, 2, 3, and 4. Then, the approximation values are calculated from the weight of different evaluation factors in the corresponding criterion layer.

$$\begin{aligned} \widetilde{W}_1 &= [\,0.377 \;\; 0.090 \;\; 0.093 \;\; 0.171 \;\; 0.275\,], \\ \widetilde{W}_2 &= [\,0.137 \;\; 0.352 \;\; 0.268 \;\; 0.118 \;\; 0.132\,], \\ \widetilde{W}_3 &= [\,0.217 \;\; 0.055 \;\; 0.194 \;\; 0.054 \;\; 0.165 \;\; 0.054 \;\; 0.109 \;\; 0.162\,], \\ \widetilde{W}_4 &= [\,0.117 \;\; 0.274 \;\; 0.512 \;\; 0.108\,]. \end{aligned} \tag{10}$$

4.2.2. Consistency Check. According to the judgment matrix created, the maximum eigenvector is calculated, and the weights among the factors of teaching quality evaluation in different criteria layers are obtained. Experts combine their personal knowledge and accumulated experience to get the value. Therefore, the X_i/X_j value cannot be accurately judged. It can only be evaluated from a scientific perspective. The consistency of the judgment matrix should be checked, and the compatibility between errors and data should be reduced.

This study uses the CR = CI/RI to test the judgment matrix's consistency. The judgment matrix's general consistency index is called CI. The following is the calculation equation:

$$\mathrm{CI} = \frac{1}{n-1}(\lambda_{\max} - n). \tag{11}$$

Table 2: RI judgment matrix values.

N	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.59	0.91	1.13	1.24	1.33	1.42	1.46

An average random consistency test is called RI in the judgment matrix. The RI values of the judgment matrix are listed in Table 2. If the weight factor of the classification is appropriate and the CR value in the 1–9 matrix of order judgment is less than 0.1, consistency requirements are satisfied by the judgment matrix; otherwise, it should be readjusted until it is fulfilled and then halted.

A judgment matrix needs to be included in (11); $\lambda_{\max} = 4.0413$, and the calculated CI value is 0.0107. Since the CR value is less than 0.1, a judgment matrix's evaluation outcomes are consistent, indicating that the weight factor allocated is reasonable. The importance of the assessment criteria for teaching material, teaching attitudes, classroom instruction, and teaching techniques can be determined from the given computation.

4.3. Constructing the Teaching Quality Evaluation Matrix. The weight of the evaluation factors in the various criteria layers can be determined in this work by utilizing the AHP analytic hierarchy method after identifying the various components in the criterion layer of the teaching quality evaluation factors. After that, the fuzzy membership relationship, also known as the membership relationship, is calculated using the fuzzy comprehensive evaluation method using the associated weight coefficients of various components. Then, the following procedure is used [19]:

(1) Assessment level set

On the premise of the same evaluation criteria, the evaluation objects are divided into g grades, which are classified by V= (v_1, v_2,..., v_g). Based on the experience accumulated in the previous division of teachers 'teaching levels, the value of g is 5. The set of evaluation levels V = {Good, Good, Normal, Bad} is recorded. The best and worst scores are 100 and 20, while the difference between each level is 20.

(2) Implementing teaching quality evaluation based on statistical interface

In this examination, there are five categories of experts: supervising teachers, department leaders, managers of scientific research, students, and teachers. The trust levels of several experts are calculated in this research using the AHP approach, among which the trust values of department leaders are 0.275, teaching supervisors are 0.174, scientific research managers and students are 0.90, and teachers are 0.376. All experts evaluating the effectiveness of public art education teachers at colleges and institutions specify several levels of assessment factors at the hierarchical criterion level and choose corresponding evaluation levels of teaching quality, which are depicted using Figure 4.

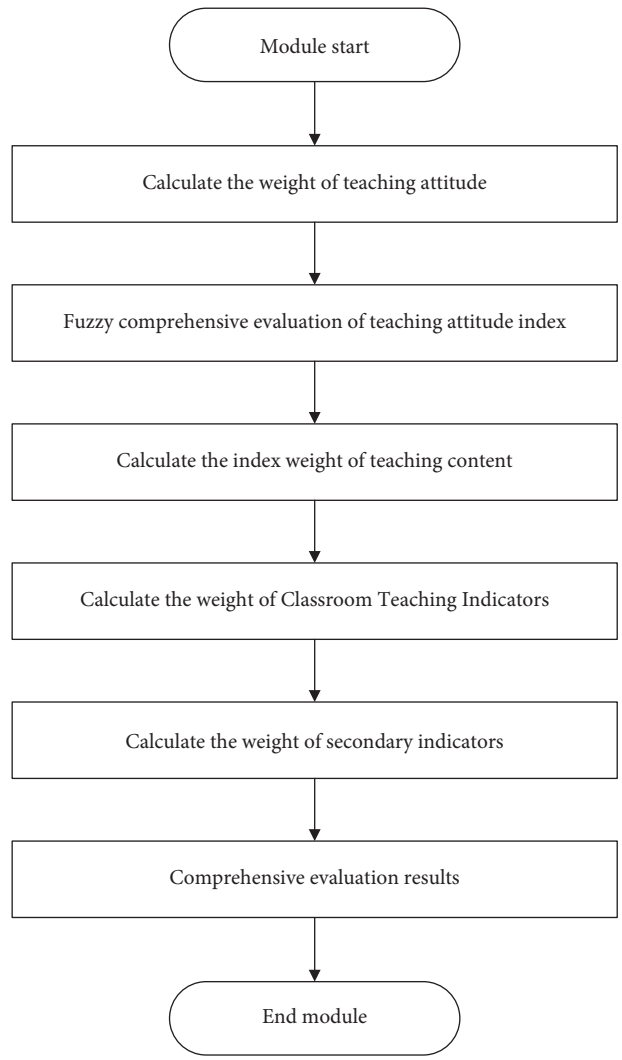

Figure 4: Flow chart for evaluating the grade of teaching quality.

(3) Constructing the fuzzy relation matrix

The number of experts with the same pixel level is randomly chosen from a set of criteria for evaluating the effectiveness of public art instruction at colleges and universities, and the number of experts that took part in this evaluation divides the results. In order to incorporate multiple elements and levels into the criterion level to build a fuzzy relationship matrix, it is possible to calculate the membership degree of different factors on the criteria level, also known as the membership degree of different levels:

$$R_k = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{15} \\ r_{21} & r_{22} & \cdots & r_{25} \\ \cdots & \cdots & \cdots & \cdots \\ r_{nk1} & r_{nk2} & \cdots & r_{nk5} \end{bmatrix}. \quad (12)$$

$$r_{ij} = \frac{y_{ij}}{N}. \quad (13)$$

Table 3: Evaluation results of teaching effectiveness for the education of public art at institutions.

Expert category	X_1	X_2	X_3	X_4	Comprehensive evaluation
Department leader	89.86	93.24	100.00	83.35	94.11
Instructional supervision	88.13	80.07	76.36	77.2	80.44
Teaching manager	83.54	89.95	96.82	91.24	90.39
Teacher	83.68	89.95	96.83	90.98	90.36
Student	97.47	92.36	89.32	92.35	92.88

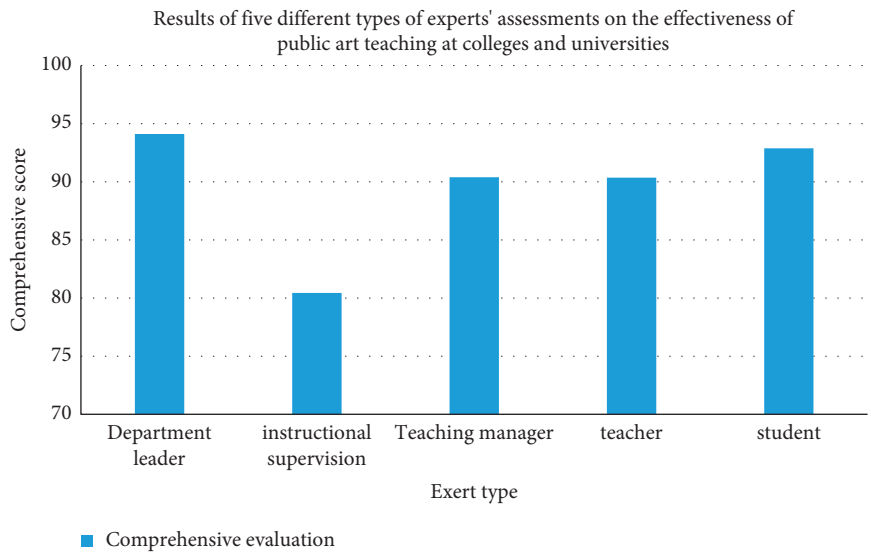

Figure 5: Results of five different types of experts' evaluations of the effectiveness of public art teaching at colleges and universities.

In (13), y_{ij} is the quantity of experts for the z-th evaluation factor of teaching quality and N is the quantity of all experts participating in this teaching quality evaluation.

(5) Evaluation results for public art education teaching quality at colleges and universities

Two aspects of the results for the effectiveness of public art education instruction at colleges and universities are described in the following.

4.4. Analysis of Public Art Education Course Evaluation Results for Teaching Quality. In accordance with the fuzzy comprehensive teaching quality evaluation's maximum membership principle, assuming $b_{\max} = [b_1, b_2, b_3, b_4, b_5]$, the b_1, b_2, b_3, b_4, b_5 teaching quality evaluation levels are the corresponding maximum component b in the V evaluation level set.

The weights of various evaluation elements are determined using the fuzzy comprehensive evaluation formula combined with the AHP approach, and then, the primary and secondary fuzzy comprehensive evaluation results are generated. Based on the results of the primary and secondary evaluations, the teaching quality assessment results for public art teaching programs at colleges and universities are computed and shown in Table 3. The results of a thorough examination of teaching quality conducted by five different categories of experts are shown in Figure 5.

Figure 5 displays the results of a proper review of teaching quality conducted by five experts using the fuzzy comprehensive evaluation formula and AHP technique in conjunction with the four criteria levels of teaching attitude, teaching material, teaching methods, and classroom teaching. The department leader received a score of 94.11 from the five experts, followed by scores of 90.36 from other teachers, 92.88 from students, 90.39 from teaching managers, and 80.44 from teaching supervisors. The department leader received the highest overall score for teaching quality from the five experts.

4.5. Fuzzy Comprehensive Test Evaluation Results. The effectiveness of college and university teachers' instruction is evaluated using this system. Teaching supervisors and educational administrators can evaluate all teachers in the college, but each student and leader can only review the teaching circumstances of public art teachers in the department [20]. The fuzzy comprehensive system for evaluating teaching quality will calculate the weights of various indicators according to the constructed evaluation fuzzy model and generate the corresponding fuzzy comprehensive evaluation results after other teachers, students, administrators of the academic affairs office, teaching supervisors, department leaders, and other teachers of public art courses have been evaluated. In this study, 10 public art education instructors from colleges and universities were chosen at

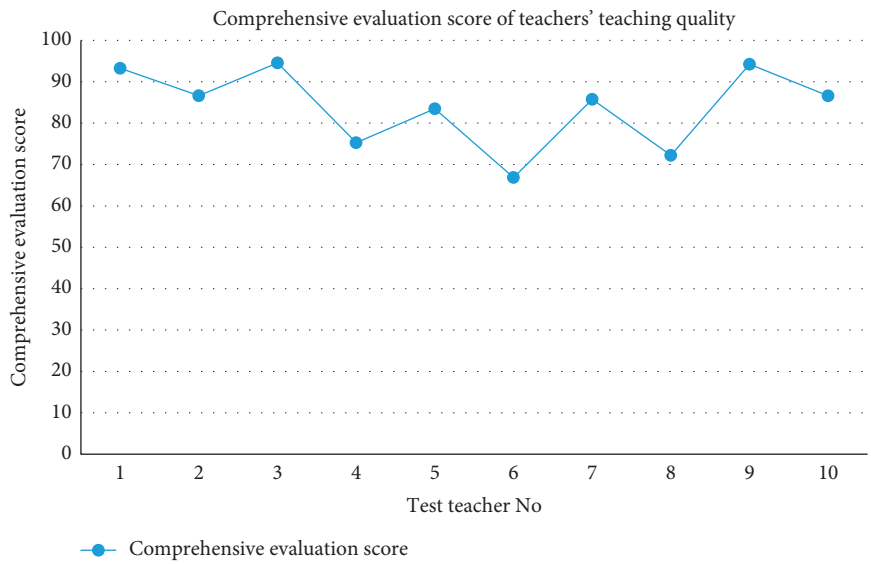

Figure 6: Final grade of teaching effectiveness assessment for teachers.

random for evaluation, and each teacher's overall evaluation score was computed. The results are displayed in Figure 6.

According to the thorough assessment ratings of the teaching quality of the 10 teachers of public art education courses displayed in Figure 6, one of the ten teachers is thought to have low teaching quality; the other nine teachers all received more than 70 points, meeting the minimal standards for teaching public art education courses. The use of this teaching quality evaluation can significantly enhance the effectiveness and quality of college and university teaching as well as increase the fairness, effectiveness, and accuracy of the evaluation results.

5. Conclusions

In recent years, China's colleges and universities have seen daily growth in enrolment and a rise in the value placed on higher education. The public art education course is intended for students who are not specializing in art, and the quality of the teachers is inconsistent. Colleges and universities are unable to evaluate teachers' ability to teach with accuracy. Due to this, some teachers that lack classroom experience teach in colleges and universities using ineffective teaching strategies. Long-term teaching degrades the standard of college and university public art education courses, making it challenging for students to absorb pertinent course material in the classroom. Therefore, this study creates an education course assessment model by fusing the AHP fuzzy comprehensive evaluation technique with the comprehensive evaluation method to assess the teaching quality of public art education courses offered at colleges and universities. This strategy incorporates effective public art teachers to determine a comprehensive score of each teacher's instructional quality and to assess each teacher's effectiveness based on that score. The system can concurrently save the teaching quality evaluation scores of all instructors in colleges and universities as well as query the teacher evaluation results on the network to improve the efficacy of teaching quality assessment inquiries. Five different types of specialists provide complete evaluation findings based on the four categories of teaching attitude, teaching material, teaching methods, and classroom instruction, with department leaders awarding the highest score of 94.11 out of 100. [15–17].

Data Availability

The corresponding author can be reached for a reasonable request for the datasets used and/or analyzed in the current work.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Evaluation of Economic Benefits and Ecological Environment Impact of Export Trade in Anhui Free Trade Zone

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Nowadays, the scale of international trade is expanding at a great pace, leading to the development of the economy of different countries. Global industrialization and urbanization are developing with each passing day, and this fast economic expansion is putting a tremendous impact on the environment. Like the other countries, the scale of Chinese export trade is also increasing with time, resulting in the stable economy of our country. With the improvement of living standards, people are continuously demanding high environmental facilities. Further, the impact of trade (enterprises, companies, industries, etc.) on the ecological environment has become a worldwide problem because economic progress brought forth by trade expansion may directly affect the environment by causing pollution to rise or the degradation of natural resources. This indeed is a serious issue; therefore, various countries have started focusing on the impact of export trade on the ecological environment. In recent years, the issue of economic benefits and the environmental impact of export trade has become a hot topic of research. Therefore, this study focuses on the relationship between trade, economy, and environmental quality in China. For the accomplishment of our research study, we selected Anhui free trade zone (FTZ) as an example to analyze the interaction between the economic benefits of Anhui export trade and the local environment. It is among the top trading provinces in China having a faster economic development. In order to accurately study the economic benefits and environmental impact of export trade in the Anhui FTZ, this paper selects industrial waste gas, wastewater, and solid waste to establish an export trade environmental impact indicating system. After comparative analysis, three factors that include industrial soot (dust) emissions for export trade, chemical oxygen demand for trade, and general industrial solid waste dumping and discards are selected to evaluate the impact on the environment of the free trade zone. Based on this, the export trade environment vector autoregressive (VAR) model is established, and the variance decomposition method is used to analyze the dynamic impact of various factors on the environmental impact index. Further, we established an economic benefit VAR model based on the export economic benefit index (EI), export value (EV), and export product concentration (EPC) index and judged the economic benefit of the Anhui free trade zone based on the contribution rate of the obtained three factors. The experimental results show that the export volume and product concentration directly affect the economic benefits of the region, and at the same time, the expansion of export trade promotes the growth of economic benefits.

1. Introduction

A free trade zone (FTZ), also known as a foreign trade zone, is referred to as an area where products can be imported in, handled, manufactured, or modified and then re-exported without the involvement of customs authorities [1]. The rapid development of international trade has accelerated the realization of globalization [2]. The world economy is undergoing transformation and adjustment. Therefore, the impact of trade on the ecological environment has become a worldwide problem because the economic progress brought forth by trade expansion may directly affect the environment by causing pollution to rise or the degradation of natural resources [3]. The uncoordinated development of economic benefits of export trade and the environment as well has become increasing severely. The export trade in China has

developed rapidly, its scale has been increasing, and its position in global trade is improving gradually [4, 5]. The development of export trade has enabled the economy of China to maintain steady growth. The import and export volume of China in 2020 reached 4646.32 billion Yuan, which increased by 1.5% as compared with the previous year [6]. The proportion of industrial products in the foreign trade product structure is increasing continuously. In 2020, the export value of industrial products was 2.475202 billion Yuan, of which 95.5% of industrial products were exported [7].

World trade development has elevated the problem of the relationship between trade and the ecological environment. Accelerating the development of import and export trade leads to a significant effect on the economy [8]. The in-depth analysis reveals that the development of import and export trade has a serious impact on the ecological environment [9]. According to the analysis of the export product structure in China, the export trade products manufacturing industries produce high pollution and consume a huge amount of energy [10]. Domestic energy consumption continues to increase. Through the analysis of the energy structure, coal is still the most used energy source. Consuming a large amount of coal energy materials emits a large number of pollutants into the atmosphere, pollutes the air environment, and also pollutes water resources [11]. There were 21 free trade zones in China according to a report generated by the Chinese ministry of commerce in 2021 [12]. In this study, we chose Anhui free trade zone as an example to analyze the interaction between the economic benefits of Anhui export trade and the local environment.

Anhui province is near the sea and river, and the city clusters along the river reach eight hundred miles. It is the area where the economic sectors are connected to each other. The 8th most populated province in China is Anhui. It is the 12th most inhabited province among the 34 provinces in China and based on the area it is the 22nd biggest province of China [13]. The total area of the Anhui pilot free trade zone is 119.86 square kilometers. There are three areas in Anhui pilot free trade zone, namely, Hefei, Wuhu, and Bengbu. Each area consists of 64.95 square kilometers, 35 square kilometers, and 19.91 square kilometers, respectively. Therefore, with the establishment of the three free trade zones in Anhui province, the export trade volume has increased and the economy has developed rapidly. The overall export trade of Anhui province has maintained a state of increasing year by year. However, economic development has brought serious environmental pollution problems, and the discharge of industrial wastewater, waste gas, and solid pollutants has continued to increase. The total import and export trade of Anhui province in 2010 was 24.28 billion US dollars. In 2020, the total import and export trade volume reached 78.7 billion US dollars with an average annual growth of 4.95 billion US dollars, and the economic growth rate was relatively high over the same period. So, import and export trade is an important factor that affects economic growth.

This study selects Anhui province's export trade economic index, export value, and export product concentration from 2010 to 2020 and establishes a vector autoregressive (VAR) model. This study uses the variance decomposition technique to study the relationship between export trade and economic growth in the Anhui trade zone to accurately analyze the impact of Anhui's export trade on economic growth and to achieve a healthy growth state between Anhui's export trade and economic growth. Through the evaluation and analysis of the economic benefits and environmental impact of the Anhui free trade zone, this study is conducted to accelerate the long-term and stable development of the Anhui free trade zone's export trade and also maintain an attractive image in the process of international trade. This study analyzes the economic benefits and environmental impression factors of the Anhui free trade zone through the establishment of a VAR model and combines the impact of environmental benefit factors and economic benefit factors on the regional economy. This research work finds a balance maintained economic growth without causing damage to the environment, which is conducive to promoting the development of Anhui province's export trade and achieving coordinated development with the environment. Figure 1 shows the free trade zones in China.

The main contributions of this study are as follows: (1) in this study, we selected the Anhui free trade zone as an example to analyze the interaction between the economic benefits of Anhui export trade and the local environment. (2) In order to accurately study the economic benefits and environmental impact of export trade in the Anhui free trade zone, this study selects industrial waste gas, wastewater, and solid waste to establish an export trade environmental impact indicating system. On the basis of this, we established an export trade environment vector autoregressive (VAR) model and used the variance decomposition method to analyze the dynamic impact of various factors on the environmental impact index. (3) We closed our study with a summary of the economic benefits and ecological environment impact of export trade in the Anhui free trade zone.

The rest of the article is structured as follows: Section 2 lays out the literature review, Section 3 represents the materials and methods, and Section 4 illustrates the results and discussion. Finally, in Section 5, we conclude our research study.

2. Related Work

FTZ is an important means of adapting to globalization and establishing a comparative advantage in global trade. Since the suggestion of the FTZ concept, research has focused on its policy effects as well as the relationship between FTZ and novelty and economic growth. According to the innovation-driven vision of FTZ, it clearly contributes to and enables the capacity for regional innovation [14]. When the FTZs initially became popular, the majority of researchers examined their effects on cities from the angles of finance, commerce, foreign direct investment, and green development. From the financial point of view, Yao and Whalley [15] believe that the economic liberalization and floating exchange rate policies introduced by the FTZ increase capital liberalization and

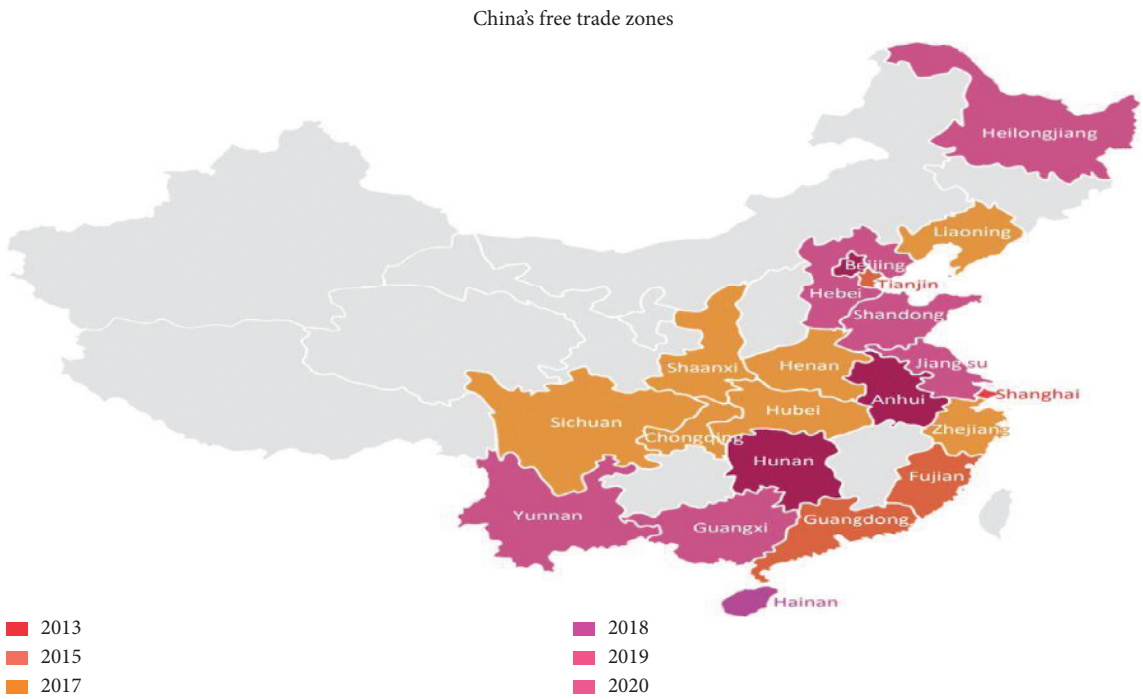

Figure 1: Free trade zones in China.

encourage financial openness. Jiang et al. [16] investigated the overall impact of the formation of the China (Shanghai) pilot free trade zone (SPFTZ) on green total factor productivity (GTFP) in Shanghai using synthetic control techniques based on microscopic data. The experimental results show that in Shanghai SPITZ has promoted the GTFP. Hongyan Wang et al. [3] analyzed the effect of China (SPFTZ) on GTFP in the YRDUA using data from Yangtze-river delta urban agglomeration (YRDUA) from 2003 to 2018. It examines the influence mechanism using the regression discontinuity (RD) approach and the mediating effect model. Lin Fan et al. [17] analyzed the evaluation of Hefei's economic and technical development area to measure the effectiveness of industrial symbiosis.

The relationship between commerce, the Chinese economy, and environmental quality was analyzed by Zhou [18]. The environmental efficacy of thirty Chinese provinces and cities was calculated using the Super-SBM model in the context of these interactions to determine the levels of regional inequality. Li and Yeung conducted research on regional economic development in China and concluded that the existence of global corporations will increase regional development disparities in the context of globalization [19]. He [20] used an empirical dynamic panel data model to examine whether financial reform may have an impact on exports or not. Using two estimating techniques (OLS and GMM), they concluded that the variable representing financial deregulation is positive and insignificant at the 5% level. Lin et al. [21] created cross-sectional spatial regression and panel and spatial regression models to investigate the stimulating impacts of financial development on economic growth in China. They concluded that while some areas of the financial sector may have a beneficial impact on economic growth, the impact of other sectors is uncertain.

From the summary of existing research, it is found that worldwide industrial development has increased recently and this rapid economic growth has severely stressed the environment. Therefore, the impact of trade on the ecological environment has become a worldwide problem, because trade expansion and economic progress directly affect the environment by causing pollution to rise or the degradation of natural resources. The issue of trade and the environment has become more serious as global trade has grown. The economy is affected by blindly accelerating the growth of import and export trade. China is the world's largest exporting country. Because of this, not only China's environment is suffering, but China also significantly contributes to global environmental degradation. If we do not follow the coordinated development of environmental protection and opening and only pursue the scale and quantity of export products, then it will seriously damage the ecological environment in China. In this paper, we analyzed the evaluation of economic benefits and ecological environment impact of export trade in the Anhui free trade zone of China.

3. Materials and Methods

3.1. Study Area and Data Collection. Anhui province is located in the east of China, next to the coastal provinces of Jiangsu and Zhejiang. Hefei is the capital of the Anhui province. There are three areas in Anhui PFTZ, namely, Hefei, Wuhu, and Bengbu. The total area of the Anhui province is 140,200 km^2. It is the area where the economic sectors are connected to each other. In this study, we select the export data of Anhui province as the research object and collected the export data from the "Anhui Statistical Yearbook" 2010–2020. Pollutant emissions data is obtained from the "China Environmental Yearbook." Figure 2 shows the location of Anhui province.

Figure 2: Map of the research area.

3.2. Establishment of an Environmental Impact Indicator System for Export Trade in Anhui FTZ. In the process of establishing the environmental impact indicator system for export trade in Anhui FTZ, this study selects industrial wastewater, industrial waste gas, and solid waste. Chemical oxygen demand for export trade, industrial smoke (dust) emissions, and general industrial solid waste dumping and discarding are further selected as the basic indicators. Table 1 shows the specific indicators used in this study.

3.3. Establishment of a VAR Model for the Export Trade Environment in Anhui FTZ. The VAR model is built on the bases of statistical analysis. Its main goal is to anticipate the correlation time series between the variables, assess the time series between distinct variables, and treat all endogenous variables in the system as functions of the lag value of other variables. After conflicts occur, other variables in the system are also affected. The following equation is used for the establishment of a VAR model:

$$\begin{Bmatrix} y_{1t} \\ y_{2t} \\ \dots \\ y_{kt} \end{Bmatrix} = \Phi 1 \begin{Bmatrix} y_{1t-1} \\ y_{2t-1} \\ \dots \\ y_{kt-1} \end{Bmatrix} + \cdots + \Phi p \begin{Bmatrix} y_{1t-p} \\ y_{2t-p} \\ \dots \\ y_{kt-p} \end{Bmatrix} + H \begin{Bmatrix} x_{1t} \\ x_{2t} \\ \dots \\ x_{dt} \end{Bmatrix} + \begin{Bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \dots \\ \varepsilon_{kt} \end{Bmatrix}, \quad t = 1, 2, \dots, T. \tag{1}$$

The following equation represents its vector representation:

$$y_t = \Phi_1 y_{t-1} + \cdots + \Phi_p y_{t-p} + H x_t + \varepsilon_t, \quad t = 1, 2, \dots, T. \tag{2}$$

Table 1: Environmental impact index system of export trade.

First-level indicator	Secondary indicators
Environmental indicators	Chemical oxygen demand for export trade Industrial smoke (dust) emissions General industrial solid waste dumping and discarding

In the above equation, y_t represents the k-dimensional endogenous variable column vector, x_t describes the d-dimensional exogenous variable column vector, p shows the lag order, and T illustrates the actual number of samples. Variable "H" represents the k-dimensional disturbance vector, and it is the coefficient matrix to be estimated in the $k \times k$-dimensional matrix and the $k \times d$-dimensional matrix. ε_t represents the k-dimensional disturbance vector.

In this paper, we established a VAR model to analyze the export trade environment of Anhui FTZ. This model analyzes the impact of various influencing factors on the environmental index through variance decomposition and impulse response methods. It sets NI to represent the environmental impact index and PE to represent the proportion of export pollution. The following equation represents the environmental VAR model constructed in this paper, where c represents the exogenous variables of the model:

$$\begin{pmatrix} NI_t \\ PE_t \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix} + \Phi_1 \begin{pmatrix} NI_{t-1} \\ PE_{t-1} \end{pmatrix} + \cdots + \Phi p \begin{pmatrix} NI_{t-p} \\ PE_{t-p} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}, \quad t = 1, 2, \dots, T. \tag{3}$$

In the above equation, "P" represents the interval order and "T" represents the number of samples. In the 2 × 2-dimensional matrix, "$\Phi 1, \dots, \Phi p$" describes the coefficient

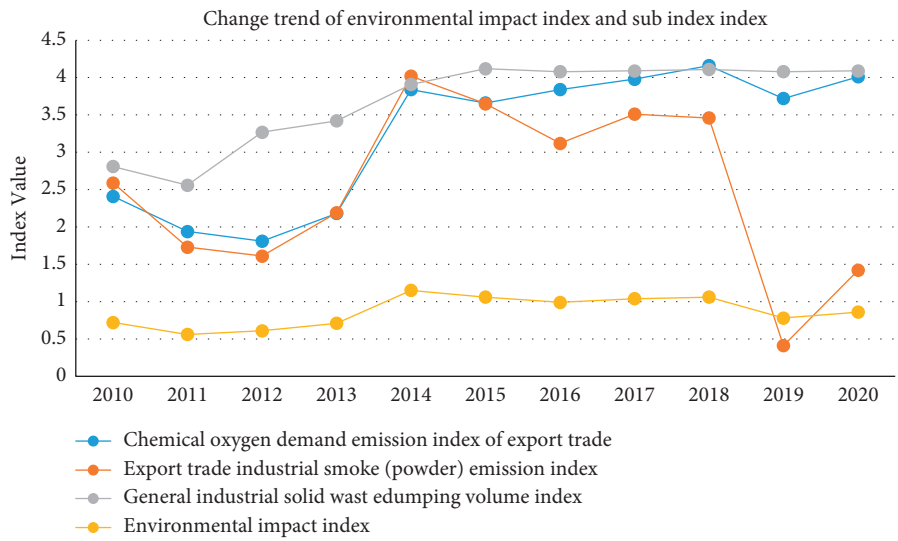

Figure 3: The environmental impact indicators and subindices of Anhui province's export trade from 2010 to 2020.

matrix with estimates, and ε_t shows the 2-dimensional disturbance column vector.

3.4. Establishment of an Economic Benefit VAR Model for Anhui FTZ. In order to study the economic benefits of export trade in the Anhui FTZ, we proposed a VAR model for Anhui FTZ. In this model, "EI" represents the economic efficiency index of export trade, "EX" shows the export value, and "EXS" illustrates the concentration of export products. After taking the natural logarithm of EX, 1nEX is obtained. This model analyzes the dynamic structural relationship among the indices of Anhui FTZ. The following equation represents an economic benefit VAR model:

$$\begin{pmatrix} EI_t \\ \mathrm{In}EX_t \\ EXS_t \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} + \Phi \begin{pmatrix} EI_{t-1} \\ \mathrm{In}EX_{t-1} \\ EXS_{t-1} \end{pmatrix} + \cdots + \Phi_p \begin{pmatrix} EI_{t-p} \\ nEX_{t-p} \\ EXS_{t-p} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{pmatrix}, \quad t = 1, 2, \ldots, T. \tag{4}$$

In equation (4), "P" represents the interval order and "T" illustrates the number of samples.

In 4×4-dimensional matrix, "$\Phi 1, \ldots, \Phi p$" represents the coefficient matrix with estimation, and ε_t describes the 4-dimensional disturbance column vector.

4. Results and Discussion

4.1. Results of Environmental Impact Analysis of Anhui FTZ. According to the established proposed environmental impact assessment index system of Anhui province export trade, we collected and sorted out the original data of Anhui province from 2010 to 2020 and then normalized each index to obtain the corresponding weight index. Further, we drew the environmental index with the trend of subindices, as shown in Figure 3.

According to the above line graphs of industrial soot (dust) emissions, chemical oxygen demand, and general industrial solid waste dumping and discarding from export trade in Anhui Province FTZ, the three index curves are basically the same. Only industrial soot (dust) emissions were low in 2019 with an index of 0.41, which shows that all three indicators affect the environmental index. 2014 is the year with the highest industrial soot (dust) emissions of the three indicators in the Anhui FTZ from 2010 to 2020. The energy consumption of Anhui province in 2014 reached 125 million tons of standard coal and the energy consumption increased by 2.7% compared to the previous year. The exports of Anhui reached 31.52 billion US dollars, which increased 11.6% year by year. The rapid development of such enterprises has increased energy consumption, which caused the emissions of these three indicators to increase. The environmental impact index has been in a stable state from 2010 to 2020, in which only the environmental impact index exceeded 1 in 2014, 2015, 2017, and 2018, and the rest were less than 1, which indicates that the environmental impact index was exported during these four years. The emissions of soot (dust) from the trade industry, the chemical oxygen demand for trade, and the dumping and disposal of general industrial solid waste have a greater impact on the Anhui FTZ.

4.2. Results of Environmental Benefits of Export Trade in Anhui FTZ. Based on the established VAR model of the environmental benefits of export trade in Anhui FTZ, this study substitutes the above environmental impact subindices of Anhui province from 2010 to 2020 into the VAR model and uses the variance decomposition method to analyze the dynamics influences of different factors on the environmental impact index. Figure 4 shows the contribution rate of the economic impact index and the proportion of export pollution to the environmental impact index. The abscissa is

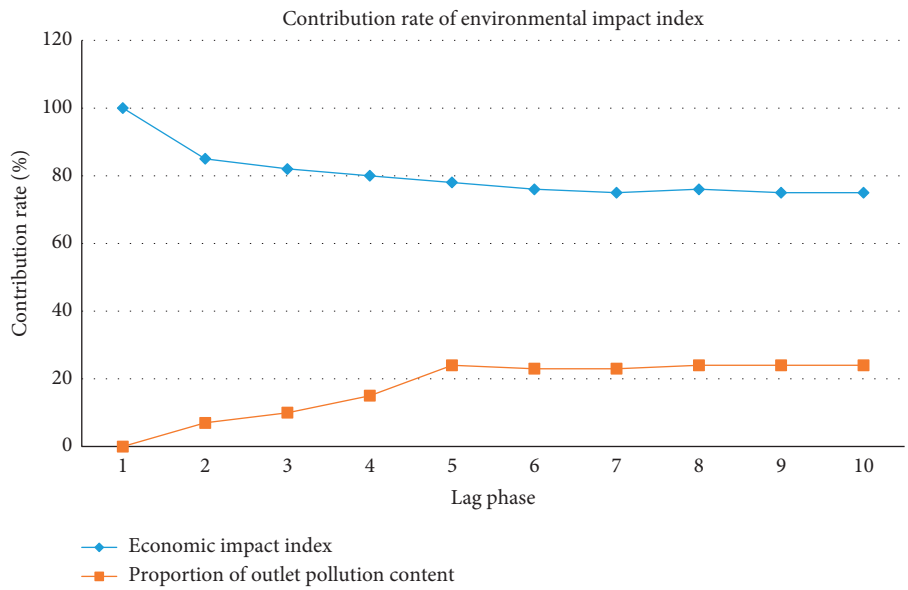

Figure 4: The contribution rate of the economic impact index and the proportion of export pollution to the environmental impact index.

the lag period of the impact, and the ordinate is the contribution rate of each variable to the change of the environmental impact index.

Figure 4 shows the contribution rate of the economic impact index and the proportion of export pollution to the environmental impact index. According to the data used in Figure 4, the environmental impact index itself changes. The contribution rate of the environmental impact index from the first to the fifth period is in a state of continuous decline. Since the sixth period, the contribution rate has been maintained at about 76% and is in a stable state. From the second lag period, the contribution of the export pollution content to the environmental impact index has continuously increased and reached its peak value in the fifth lag period. Since then, the contribution rate has been around 24%. The data show that the proportion of export pollution has a promoting effect on the environmental impact. The export environmental index of the Anhui province FTZ and the proportion of export pollution maintained a stable relationship with each other.

4.3. Results of Economic Benefits of Export Trade in Anhui FTZ. In this study, the Anhui FTZ export economic benefit index (EI), export value (InEX), export product concentration (EXS), and other indexes are substituted into the established economic VAR model for the correlation analysis. The results show that the correlation coefficient between EI and InEX was 0.97, and the correlation coefficient between EI and EXS was 0.89, which indicates that the correlation between the economic benefit index, export value, and product concentration is strong. Here we used variance decomposition analysis to study the degree of co-occurrence of economic benefit index, export value, and export product concentration. The obtained results are shown in Figure 5. The horizontal axis is the lag period

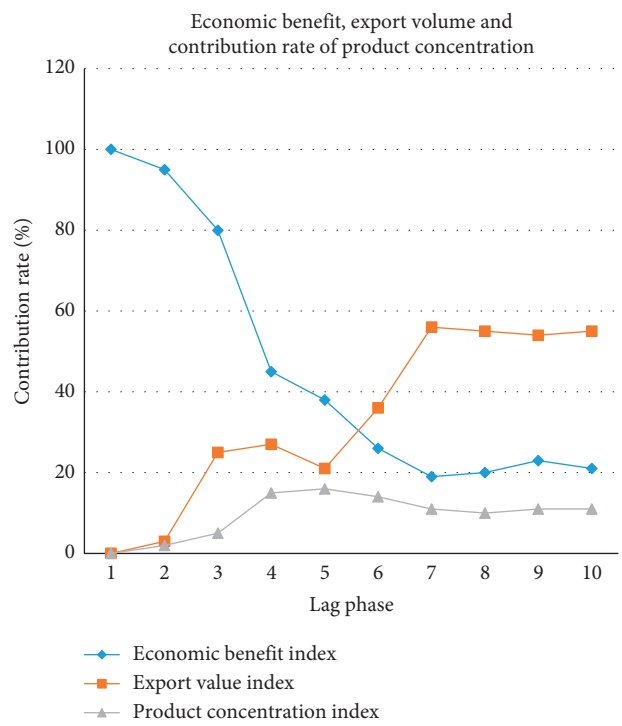

Figure 5: Contribution rate of economic benefit index, export value, and product concentration index.

of the impact effect, and the vertical axis represents the contribution rate of the variable to the change of the social benefit index.

From Figure 5, we conclude that the economic benefit index's change contribution is in a state of decline from the first period to the seventh period, and after that, it maintains at about 19%. The export value contributed most to the change in the economic benefit index. From the first to the seventh period, it maintained a rapid increase and thereafter

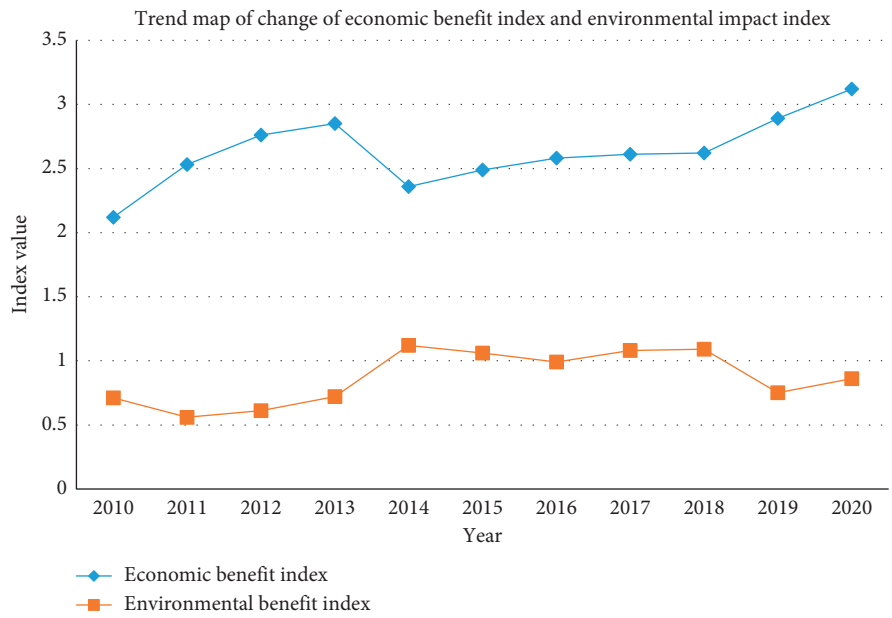

Figure 6: The change trend of the economic benefit index and environmental impact index from 2010 to 2020.

the contribution rate remained at about 56%. The contribution of export product concentration to the economic benefit index has gradually increased from the first period to the seventh period by about 11%. Based on the analysis of the results, the economic index of export trade in Anhui FTZ is increasing, and the export volume and product concentration index directly affect economic benefits. The scale of export trade promotes the rapid growth of economic benefits. If the export value is changed, the corresponding export trade-economic benefit index and product concentration also show a linear change. After the economic benefit index is changed, the corresponding product concentration also changes. Hence, it can be concluded that the economic benefits of export trade in the Anhui FTZ are in a state of continuous growth.

4.4. Comprehensive Analysis of Export Economic Benefits and Environmental Impact of Anhui FTZ. Based on the above data analysis, the export economic benefits and environmental impact data of the Anhui FTZ are obtained. The export trade data of Anhui province from 2010 to 2020 is analyzed, and finally, the export trade-economic index and environmental impact index are obtained. Figure 6 shows the change trend of the economic benefit index and environmental impact index from 2010 to 2020.

Observing the above economic benefit index and the environmental impact index change trend chart, we can conclude that the export trade-economic index of Anhui FTZ is generally rising and the environmental benefits fluctuate up and down. The relationship between these has a positive correlation and after calculating the correlation coefficient between these indexes is 0.65. As the economic benefit index increases, the environmental impact index also continues to rise. Therefore, under the premise that the export trade of the Anhui FTZ brings economic benefits to the region, it will also cause environmental pollution to a certain extent.

4.5. Discussion. The relationship between the economic index of export trade and the environmental index of the Anhui FTZ from 2010 to 2020 has been declining which indicates that the industry in the Anhui FTZ during this period is dominated by high pollution. The rapid development of export trade causes environmental pollution. The positive correlation changes between the economic benefit index and environmental impact index indicators from 2011 to 2014 prompted the positive correlation between the economic benefits of the Anhui FTZ and the environmental impact index. These positive correlations indicate that the "energy-saving and emission reduction" measures in Anhui production areas have achieved initial results. The Anhui zone's export trade industry has changed from a traditional high-polluting industry to a low-polluting export trade zone.

After the reform and opening, Anhui province's labor and resources have played an important role in export trade and shown rapid growth in export trade. However, from the perspective of environmental quality, the impact on export trade is relatively low. In the process of analyzing the impact of environmental quality and natural resources on trade volume, the export resources are regarded as a fixed value and the negative external effects caused by pollution affected the market pricing mechanism.

5. Conclusion

In this paper, we select Anhui FTZ to analyze the interaction between the economic benefits of Anhui export trade and the local environment. In order to accurately study the

economic benefits and environmental impact of export trade in Anhui FTZ, first of all, we collected and sorted out the original data of Anhui province from 2010 to 2020 and then normalized each index to obtain the corresponding weight index. In this paper, we proposed an evaluation index system for the environmental impact of the Anhui export trade based on three indicators which include industrial soot (dust) emissions for export trade, chemical oxygen demand for trade, and general industrial solid waste. The analysis results show that the three indicators of the Anhui FTZ in 2014 had the largest emissions. In the same year, the environmental impact index also reached 1.15 which is the highest in 11 years indicating that the three indicators have a great impact on the environmental impact index. Further, we also proposed a VAR model for the economic benefit of export trade in the Anhui FTZ using the variance decomposition method to analyze the contribution rate of the economic benefit index, export volume, and export product concentration index. The experimental and analysis results show that the contribution rate of the economic benefit index's change contribution has been in a state of decline from the first period lag period to the seventh period and after that maintained at about 19%. The contribution of export product concentration to the economic benefit index has gradually increased from the first period to the seventh period by about 11%, indicating that the export value is changing with time. The export value contributed the most to the change in the economic benefit index. From the first period to the seventh period, there was a rapid increase, and thereafter, the contribution rate remained at about 56%. Through a comprehensive analysis of the export economic benefits and environmental impact of the Anhui FTZ, we observed that the correlation coefficient between the economic benefit index and the environmental impact index was 0.65. As the economic benefit index increases, the environmental impact index also continues to rise. Therefore, under the premise that the export trade of the Anhui FTZ brings economic benefits to the region, it also causes environmental pollution to a certain extent.

Data Availability

The data used to support 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

Measurement and Parity of Low-Carbon Economic Development Level for Guangzhou Using the SEM Model

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Due to the major energy consumer and carbon emission, China must change the previous extensive economic development method categorized by great energy consumption, high pollution, and great emissions and develop a low-carbon economy. As a result, this research focuses on the measurement and assessment of low-carbon economy growth in Guangzhou. It contains pertinent study findings as well as the most recent research developments at home and abroad. Furthermore, it searches for and investigates limited socioeconomic development theories, structural model systems, and validity and reliability analysis methodologies. Besides, considering the current condition of low-carbon financial growth in Guangzhou and the issues it faces, this study explores and analyses the key variables impacting the growth of a low-carbon economy. Finally, using the statistical analysis program such as LISREL 8.80, the structural equation model is fitted and changed based on the data validity analysis and test. It generates the measurement and evaluation model data of Guangzhou's low-carbon economic development level.

1. Introduction

These days the climate is changing rapidly, and we should recognize that changing climate has tremendously affected and will continue to affect societal growth and sustainable progress across the globe. As per estimates, the entire expenses and hazards of changing climate will be comparable to dropping at minimum of 6% of world GDP every year, with this cost potentially rising to 21% of world GDP if a broader variety of effects and dangers are considered [1]. To reduce the enormous hazards caused by changing climate, a much additional ecologically approachable growth plan should be implemented. The Chinese management did, in fact, pay consideration to this issue a small number of ages ago. According to the economic white paper [2], China is experiencing huge problems from changing environment and may face an energy source problem by 2030, with the nation potentially relying on energy imports for 75% of its overall primary energy demands. Since its inception, the low-carbon industry has been regarded as a promising development pattern capable of reducing carbon emissions while addressing climate change issues.

Presently, cities are becoming the epicenters of social-economic growth and human deeds. They play crucial roles in local, state, and worldwide growth [3]. Cities, which house fewer than half of the worldwide people, are responsible for the vast majority of manufacturing and everyday human activity and, as a result, consume a great deal of energy. It is also predicted in [1] that cities contribute around 76% of worldwide emissions of carbon. Consequently, low carbon adoption in cities is crucial to the total objective of the clean energy economy, particularly in emerging nations with fast urbanization such as China. With yearly GDP progress rates of less than 11% in current times, China has to turn out to be one of the world's main major users of energy and carbon emissions [4]. It has also been projected that the atmospheric carbon emission rate of each unit GDP of China is substantially higher than that of other nations [5]. Global consideration is increasingly focused on Chinese energy use, changes in the environment, and adaptation to climate

change initiatives. Despite increasing pressure to combat climate change, China seriously needs a low-carbon industry, by creating low-carbon cities as a critical priority [6].

Guangzhou is located in the southern part of China. It is not only the leader of our coastal port cities but also the leader of South China's economic zone. However, cities lacking energy in our country also contain this city. The total amount of consumption of energy is comparatively huge, and its energy depletion structure is mostly created by oil and coal. Among them, the total ratio of oil consumption reaches 1%, while the total proportion of coal consumption is 1%, which is the same as the overall development of China. Owing to the increasing development of China's economy, the progress of urbanization has been gradually promoted, which has resulted in the growth of total consumption of energy brought by economic growth. To better address the present economic development limits in Guangzhou, greater emphasis should be made on the low-carbon economy. According to this research direction, this paper examines and researches the growth of a low-carbon economy in Guangzhou by deeply analyzing the existing difficulties and problems and finally makes an empirical study to provide better ways to encourage the growth of the economy of low carbon in Guangzhou.

1.1. Key Contributions of This Paper. The innovations of this paper are as follows:

(1) This study defines the concept of low-carbon financial growth and explains the connotation of low-carbon financial growth from the perspectives of sustainable development, circular economy, and the environment. In addition, it explains the theoretical basis, modeling steps, technical characteristics, and data validity analysis methods of structural equation models.

(2) Apart from that, it discusses the measurement and assessment index design of low-carbon economic development levels, as well as the rationale for selecting relevant indicators. It investigates the concepts and techniques of constructing an assessment index system, ideas, and framework, as well as the collecting and screening of low-carbon economic development indicators. Finally, it develops a framework for measuring and evaluating the amount of low-carbon economic growth in Guangzhou.

1.2. Layout of the Remaining Sections in the Paper. The remaining portions of this research study are as follows: related work in our selected subject may be given in Section 2. Section 3 explains the materials we utilized and the technique we employed. Section 4 presents the design of our suggested system for low-carbon economic growth. Our experimental work and the results of that effort are discussed in Section 5. Finally, in the final portion of this paper, the intended work is finished.

2. Related Work

The first discovery of a relevant meaning for a "low-carbon economy" was in the 2003 British Government Power White Paper "The Future of Our Electricity: Building a Low-Carbon Economy," which stated that a low-carbon economy is defined as achieving more social growth by using relatively small resource consumption and environmental pollution emissions, thereby improving human standards of survival and quality of life and providing more jobs and employment [7]. Subsequently, the authors of [8] proposed that the increasing global greenhouse effect is certain to disturb the sustainable growth of the global economy. Cooperation among countries must be more efficient and fair to prevent the serious consequences of human social production on climate change. The researchers of [9] pointed out that the growth of the low-carbon economy is a public and financial growth layout with the expansion mechanism of the market economy as the core content. This mode focuses on achieving higher energy efficacy, lower consumption of energy, and lower emissions of carbon in the development of the national economy through the comprehensive use of all saving of energy and reduction skills of emission with the promotion of relevant market mechanisms and government means. Since the viewpoint of the influence factors of low carbon abroad on the national economy level, the authors of [10] conducts Granger causal test on five variables including CO_2 emissions and total energy consumption in European countries. The results show that there is a continuous correlation between CO_2 emissions and fuel consumption, and the two are causal. The US per capita income and CO_2 emissions are in the downward "U" form of the Kuznets curve of the Chinese economy and environment. Similarly, the early work of [11] used the Lotka–Volterra equation and prey-predator model to analyze the effect of population size changes on emissions of carbon.

Since the advent of the "low-carbon economy," Chinese scholars have discussed and studied its connotation and characteristics from various perspectives. The authors of [12] believe that a low-carbon economy means more effective use of energy, that is, the production of the same products with less energy to achieve the same social goals. The theoretical core of a low-carbon economy is the issue of energy effectiveness and energy arrangement. The importance of solving this issue lies in system improvement and technical growth. In this regard, the scholars of [13] highlighted that the development design of economy for low carbon is a fresh financial development design based on "three small and three high," aimed at low-carbon economic growth, and based on preservation of energy and emission decrease as the main means. While the study of [14] believes that low-carbon economic growth should be identified based on three qualities such as strategic, comprehensive, and global. The low-carbon economy is a long-term global economic development concept that involves numerous social layers. The early work of [15] once advocated that people should get rid of four kinds of misconceptions if they want to understand the low-carbon economy correctly: a low-carbon economy is a poor economy. The development of a low-carbon economy

means the complete disappearance of high energy-consuming industries. A low-carbon economy will decrease the quality of life. The technology and new energy costs needed to develop an economy of a low carbon are too high. Meanwhile, they believe that given China's existing national circumstances, initiatives such as altering the manufacturing construction and energy construction would have no substantial impact. From the viewpoint of foreign low-carbon economic-level influencing factors, the common methods used by Chinese scholars in the study of low-carbon financial growth level influencing factors include the STIRPAT model or its extended model, panel data linear regression, interpreting structure model, and so on [16]. The work of [17] used the STIRPAT model scheme to examine the main manipulating factors of emission of carbon in China's manufacturing industry. The results show that both the population structure and social wealth factors play a positive role, technology plays a negative role, and the inverted U-curve theory of environmental Kuznets does not apply to the current situation in China. The authors of [18] built an enhanced STIRPAT model. The data analysis of various factors impacting carbon emissions from 1990 to 2009 was conducted using China's relevant statistical data of the period. According to the findings, the change in per capita GDP is the most significant positive factor influencing the rise of carbon emissions, whereas the change in energy consumption intensity is the most significant negative factor. Inspired by these, we have analyzed and examined the important components driving the establishment of a low-carbon economy in Guangzhou. Our work provides the present situation of low growth in Guangzhou and the obstacles it confronts. Furthermore, the structural model is fitted and updated depending on the data reliability analysis and testing using the data analysis application LISREL 8.80.

3. Materials and Methodology

3.1. Low-Carbon Economic Development. The growth of a low future can result in significant economic advantages that will be visible shortly. Revenue could be increased by improving energy efficiency. Low-carbon skill has the possibility to generate fresh forms of development and service. They can help even the poorest states in jumping outdated methods. Furthermore, they can eliminate some of the expenditures of huge networks in the same way that smartphones reduced the need for telephone connections. Furthermore, smarter grids can enhance energy productivity and enable technological advances while lowering transmission costs.

3.1.1. Low-Carbon Economic Concepts. A low-carbon economy relies on sources of energy that emit less greenhouse gas (GHG). Since about the mid of twentieth century, human-caused GHG emissions have been the major source of climatic variation. Ongoing greenhouse gas emissions would cause long-term global changes, increasing the possibility of serious, widespread, and irreversible repercussions on ecosystems and humans. Globally shifting to a low-carbon economy might have substantial advantages both for developed and emerging nations. Many countries are developing and implementing low-emission policy initiatives. These methods aim to meet social, financial, and environmental strategic plans while lowering long-term gas emissions of greenhouse and building resilience to climate transformation consequences.

Under the background of global warming and the change from a high-carbon era to a low-carbon era, the growth of the economy emerges a low carbon as the times require. The idea of developing a low-carbon economy first appeared in government documents, and a corresponding definition was given in the UK book *The Upcoming of Our Sources: Generating a Low-Carbon Economy*: developing a low-carbon economy means economic growth with less means and less ecological pollution [19].

The growth of a low-carbon industry is a type of economic growth that prioritizes environmental sustainability while reducing the use of high-carbon energy sources such as coal and oil. With technical innovation implemented nationwide, modernization and renewable power growth minimize greenhouse emissions and produce a win-win scenario in economic growth and environmental protection. The low-carbon economy development methodology is founded on the notion of "three lows and three highs," with low-carbon advancement as the development agenda, energy efficiency and reducing emissions as the path of development, and carbon-neutral new tech as the path of development [20].

The growth of the low-carbon economy is based on low-carbon technology, low-carbon energy, low-carbon industry, low-carbon market, and low-carbon operation. Low-carbon technology is the power of low-carbon economic growth. Low-carbon development has rich connotations, which involve global changes in production methods, production methods, values, and national interests [21]. Low-carbon economic development is the basic concept of economic development. It takes low consumption of energy, low pollution, low emission, and high efficiency as its primary goal. Its core is to achieve the basic goals of low carbon, low emission, high efficiency, and high efficiency. Its core is to focus on low carbon to achieve the health and rapid and supportable growth of the economy and culture [22].

3.1.2. Possibilities for the Growth of China's Low-Carbon Economy. China, as a fast-rising economy, offers various opportunities for low-carbon economic growth. China must embrace energy-saving, emission, and clean renewable energy technologies by bolstering technology and development in key sectors with significant and competitive advantages [23]. In China, there are numerous opportunities to create low-carbon technologies, including carbon intensity management, emission reduction, and integration of renewable and energy saving [24]. Because of lower power concentration and energy efficiency, China's industrial and consumption design is constructed on high power consumption and poor saving energy technology [25]. As a result, it introduces vulnerability in energy management. Through

technical innovation, administration, and reorganization of technologies in various industries, China may readily seize chances for energy savings and low carbon emissions [26]. Low-carbon technology costs substantially less in China than in other wealthy countries. As a result, China may effectively take advantage of this opportunity to rehabilitate old industries using low-carbon technologies and establish new industries using low-carbon innovation [27]. China has a lot of promise in terms of carbon emission technology innovation and collaboration. Because of reduced technology acceptance, China lags much behind other emerging countries [28]. China must strengthen international collaboration and exchange technological achievements with foreign partners to obtain low-carbon technologies and develop a low-carbon industry [29]. Figure 1 explains a theoretical structure for China's low-carbon economy.

3.2. Scanning Electron Microscopy (SEM) Model. A scanning electron microscope (SEM) is a scientific instrument that generates a high-resolution image by scanning the part of a theme with focused energetic electrons. SEM generates images that deliver info about the surface construction and geometry of a material.

3.2.1. Fundamental Phases of SEM Model. As per [2], the fundamental processes of SEM modeling may be represented by the flowchart in Figure 2. This figure shows that even after collecting data and choosing suitable indicators, a variety of fundamental assumptions concerning the size of the sample, normalization, independence, outliers, and linearity are frequently made.

The model must then be described, which entails defining all causal pathways between variables based on some theory and fundamental theoretical understanding. The phases in the procedure include model identification and estimate. Over-recognition should be avoided during model identification that indicates that there are more parameters accessible than the set of parameters we wish to predict. A good technique for estimation should be selected for model estimation to accomplish effective model validation, which is the following stage in the SEM approach. The model has been tested, and its match efficiency is evaluated in this section, where various indexes can be used. If these indexes suggest poor match quality, post hoc alterations to the proposed model must be made. Otherwise, the model is able for proper interpretation and reporting of findings.

3.3. Structural Equation Model. Structuring equation modeling (SEM) is a quantitative analysis-based research tool that may be utilized to examine and evaluate complicated, multivariate topics [30]. Compared with the traditional regression analysis method, the structural equation model can handle multiple dependent variables at the same time. In addition, it can compare and evaluate various models, so there are not too many hypothetical constraints on the development of a low-carbon economy in Guangzhou. In addition, for some variables that cannot be directly measured, the structural equation can identify these possible variables to process the observed variables, process measurement errors during analysis, and analyze the structural relationship between the variables. SEM is a concept of SEM analysis proposed by Joreskog for the estimation of maximum probability parameters. LISREL software has been developed for complex computing processes. SEM has become a major research example in the field of social and behavioral sciences.

Variables of structural equation models include structural variables and dominant variables [31]. In structural equation models, variable relationships can be divided into internal and external relationships, that is, the relationship between recessive and recessive variables and measurement variables. A general structural equation model can be expressed by three basic matrix equations as shown in the following equation:

$$\begin{cases} \eta = B\eta + \Gamma\xi + \zeta, \\ Y = \Lambda_y + \varepsilon, \\ X = \Lambda_x + \delta. \end{cases} \tag{1}$$

According to equation (1), the first part is a structural equation that reflects the influence of each latent variable, where $\eta = \eta_1 + \eta_2, \ldots, \eta_m$ denotes the corresponding endogenous latent variable. Similarly, $\xi = \xi_1 + \xi_2, \ldots, \xi_m$ denotes the corresponding exogenous latent variable, while the endogenous and exogenous latent variables are determined by the inclusion coefficient matrix b. Besides, T and error vectors ζ are connected by linear equations, where B represents the effect of some endogenous latent variables on others, T Indicates the effect of exogenous potential on endogenous potential, and ξ represents regression residuals, which means unexplained parts of the model.

In addition to equation (1), the second and third parts define the measurement model of a latent variable based on the measurement variable (identification variable/measurement index). Here, the second part represents the endogenous measurement variable y and the endogenous latent variable such as η. Finally, the third part represents the relationship between the exogenous measurement variable x and the exogenous latent variable. Furthermore, the endogenous measurement variable y and exogenous measurement variable x utilize factor load $\wedge_y$ and $\wedge_x$, respectively. The corresponding endogenous latent variables η and exogenous latent variable are ξ. The exogenous measure variable x and the exogenous latent variable Y are represented, respectively. ξ is the associated measurement error that represents the portion that cannot be explained by the latent variable. If $E(\varepsilon) = 0$ and $E(\delta) = 0$, measurement error ε and δ, latent variables η, and ξ there is no corrections between measurement errors ε&δ and latent variables η&ξ, but if there may be possibly relationships between measurement errors and latent variables themselves.

Due to the universality of the structural equation model, the modeling process also needs to follow its rules. In this connection, Figure 3 shows specific analysis steps for structural equation models.

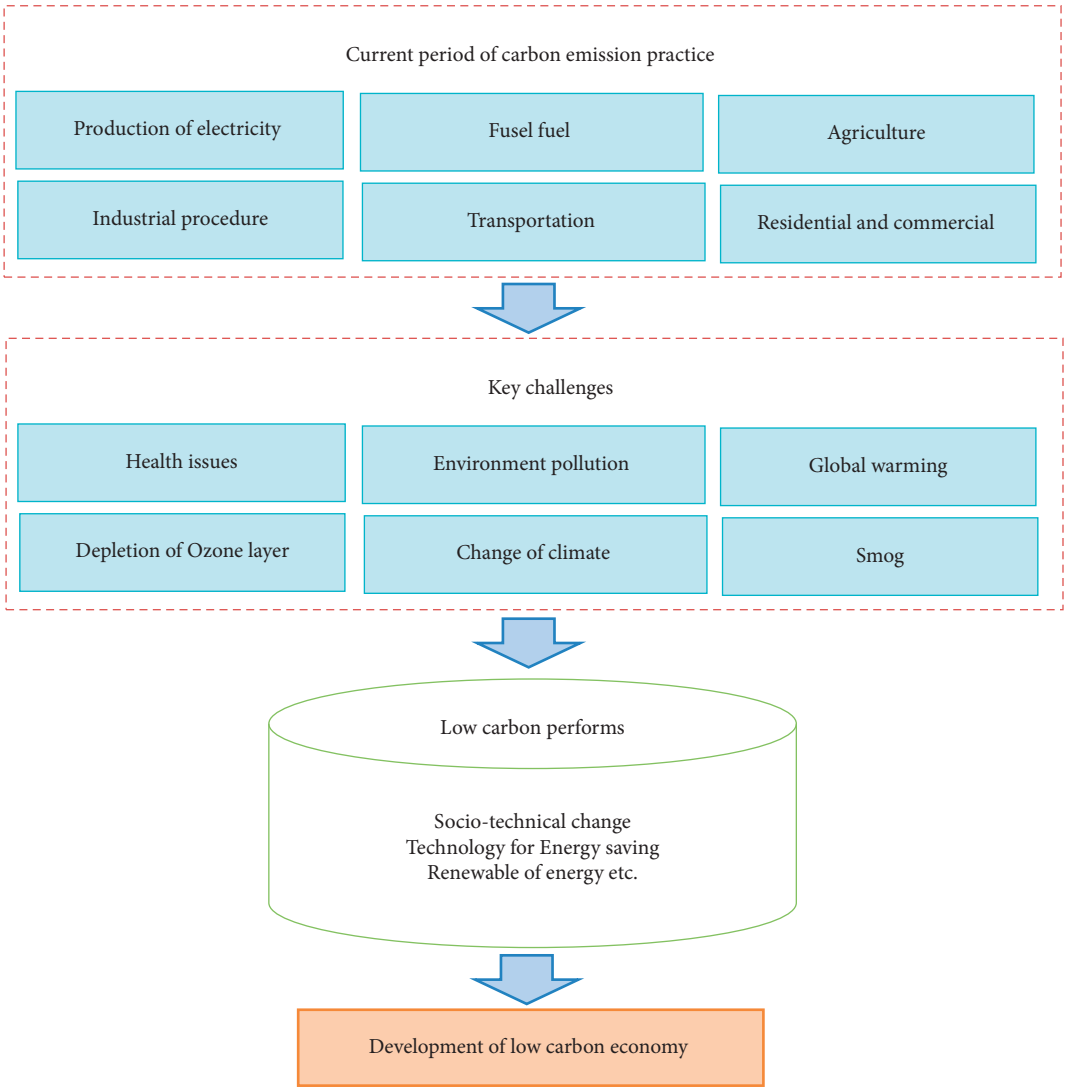

Figure 1: Theoretical framework for China's low-carbon economy.

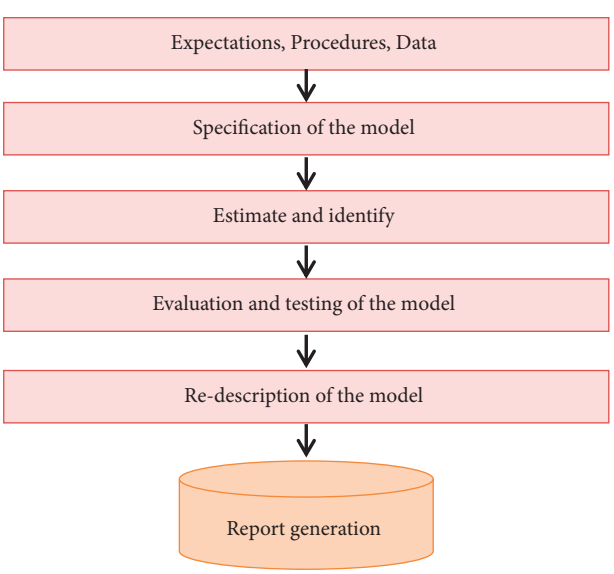

Figure 2: Flowchart of SEM modeling.

4. Design of Measurement System for Low-Carbon Economic Development Level

4.1. Energy System Design. Energy consumption is an important indicator to measure the degree of low-carbon economic development in a country or region. As a result, the development status of China's energy system is examined from three perspectives: energy supply and demand, energy consumption, and carbon emissions. The relationship between energy supply and demand includes the ratio of energy supply and demand and the elasticity of energy supply and demand.

4.1.1. Energy Supply-Demand Ratio. The ratio of energy supply to demand can reflect the dynamic change in energy supply and demand. When the ratio is greater than 1, it indicates that the energy supply is greater than the demand. The supply exceeds the demand. When the ratio is less than 1, the supply of energy is less than the demand, that is, the supply exceeds the demand. This can be calculated using the following equation:

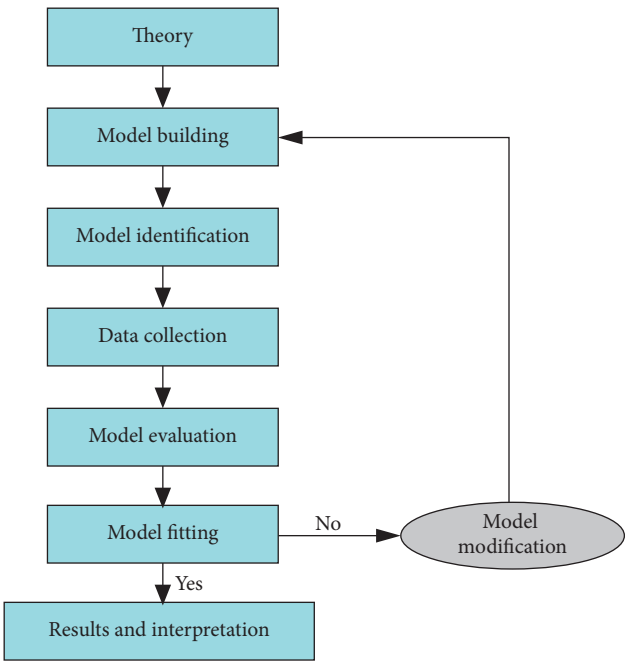

Figure 3: Specific analysis steps for structural equation models.

$$\mathrm{SDR}_E = \frac{Q_S}{Q_D}, \tag{2}$$

where Q_S represents the amount of energy supply, Q_D represents the amount of energy demand, and SDR_E represents the proportion of energy supply to demand.

4.1.2. Energy Intensity. Energy intensity and the energy consumption per unit of gross national product (GDP) can directly reflect the energy consumption and energy utilization of a country or region's economic output value. At the same time, it can also indirectly reflect the carbon emission of a country or region's economic development. Energy intensity is an important index to measure the development of the low-carbon economy. The energy intensity can be calculated using the following equation:

$$\mathrm{EI} = \frac{\mathrm{EC}}{\mathrm{GDP}}, \tag{3}$$

where EC represents the total energy consumption.

4.1.3. Carbon Emission Intensity. The intensity of carbon emission, which is the number of carbon emissions generated by the growth of the gross national product per unit, is mainly used to measure the relationship between a country's or region's economy and carbon emissions. If economic growth is accompanied by a decline in CO_2 emissions per unit of gross national product, then the country has achieved a low-carbon development model. The calculation procedure of carbon emission intensity measurement is represented in the following equation:

$$\mathrm{CDI} = \frac{\mathrm{CD}}{\mathrm{GDP}}, \tag{4}$$

where CDI denotes carbon intensity and CD denotes total carbon emission.

4.2. Economic System Design. Economic development needs to consume a large amount of energy as a support, and energy provides continuous power for economic development, which is mutually complementary. Compared with the traditional development model of "high energy consumption, high pollution, and high emission," the development of a low-carbon economy has the advantages of "high efficiency, high output value, and high efficiency." To visually reflect the level of low-carbon economic development, this study selects five indicators to measure the level of low-carbon economic development: green GDP index, per capita GDP, economic growth rate, and the proportion of tertiary industry output value, the proportion of foreign direct investment.

4.2.1. Green GDP Index. Compared with the previous GDP accounting system, green GDP is an index that considers resources, environment, and other aspects comprehensively. The larger the number, the greater the net positive effect on economic growth and the smaller the negative effect. Green GDP indicators can reflect the coordination between the ecological environment and economic development, which not only promotes economic development but also enhances the protection of the environment and the healthy development of society. The calculation procedure may be explained in the following equation:

$$\begin{aligned} I_{\mathrm{green}} &= \frac{\mathrm{GDP}_{\mathrm{green}}}{\mathrm{GDP}} \\ &= \frac{\mathrm{GDP} - C_{er} - C_{ep}}{\mathrm{GDP}}, \end{aligned} \tag{5}$$

where the green GDP index is represented by I_{green}, green GDP is denoted by $\mathrm{GDP}_{\mathrm{green}}$, environmental resource cost is denoted by C_{er}, and environmental protection service cost is represented by C_{ep}.

4.2.2. The Proportion of Tertiary Industry Output Value. The proportion of industrial structure is the proportion of the first, second, and third national industrial structures. Overall, the higher proportion of tertiary industry output value to the total national economy output value indicates that its economic structure tends to be reasonable. The development of the tertiary industry can increase the national income, but relative to the first and second production, the damage to the environment is minimal, so to develop a low-carbon economy, it is necessary to promote the development of the tertiary industry. The following equation is used to calculate tertiary industry output value:

$$\mathrm{TIR} = \frac{\mathrm{TI}}{\mathrm{GDP}}, \tag{6}$$

where tertiary industry output value ratio is represented by TIR and tertiary industry is represented by TI.

4.3. Environmental System. To develop a low-carbon economy, we must correctly recognize the role of the 3E system. Energy is the primary driving factor behind economic development, and economic growth supports energy development while simultaneously emitting a substantial amount of greenhouse gases.

4.3.1. Reaching Standard Rate of Industrial Solid Waste. The compliance rate of industrial solid waste reflects the degree of its treatment, and the higher the index, the greater the amount of industrial solid waste discharged into the environment, the less the impact on the environment, and vice versa. The compliance rate may be calculated using the following equation:

$$\mathrm{ISWR} = \frac{\mathrm{ISWD}}{\mathrm{ISWP}}, \tag{7}$$

where the amount of industrial solid waste disposal is ISWD and the amount of industrial solid waste production is ISWP.

4.3.2. Standard Acceptance Rate of Industrial Wastewater. The up-to-standard rate of industrial sewage refers to the degree of wastewater treatment. This number indicates the scale of industrial sewage discharged into the environment. The larger the number, the lower the degree of wastewater treatment, and the lower the industrial sewage discharged into the environment, and vice versa. The standard acceptance rate of industrial wastewater can be calculated using the following equation:

$$\mathrm{IWWR} = \frac{\mathrm{IWWD}}{\mathrm{IWWP}}, \tag{8}$$

where industrial wastewater treatment is represented by IWWD and industrial wastewater production by IWWP.

4.3.3. Acceptance Rate of Industrial Exhaust Gas. The industrial exhaust compliance rate reflects the level of treatment of industrial exhaust. The value of this index indicates the value of harmful gases directly discharged into the atmosphere. The industrial exhaust compliance rate can be obtained using the following equation:

$$\mathrm{IWGR} = \frac{\mathrm{IWGD}}{\mathrm{IWGP}}, \tag{9}$$

where IWGR represents the industrial exhaust compliance rate.

4.3.4. Carbon Sink. Carbon sink generally refers to the process, activity, and mechanism of removing carbon dioxide from the air. Mainly refers to how much carbon dioxide the forest absorbs and stores or the ability of the forest to absorb and store carbon dioxide. The carbon sink can be obtained using the following equation:

$$\mathrm{CS} = \rho_i \times S_i, \tag{10}$$

where the carbon absorption coefficient of a plant is expressed by ρ_i and the total area of a plant of class i is represented by S_i.

5. Experimental Result and Simulations

5.1. Calculation of Comprehensive Score of Low-Carbon Economic Development in Guangzhou. In Guangzhou, a comprehensive evaluation index layer is being developed to accurately track the growth of a low-carbon economy. This study intends to build a trend, face up to its merits and downsides, and give a theoretical framework for the environmental sustainability of a low-carbon industry in Guangzhou in the future. Based on the low-carbon economic, scientific, and technological systems, and low-carbon social and environmental systems, we have chosen a representative index layer to perform a thorough review and analysis of the development of a low-carbon economy.

Four indexes are selected, and the membership function is calculated. The relative to the forward indicator can be described by

$$\mu(x) = \begin{cases} 1, & \mathrm{suf}(f) \le f(x), \\ \dfrac{f(x) - \inf(f)}{\mathrm{suf}(f) - \inf(f)}, & \inf(f) \le f(x) < \mathrm{suf}(f), \\ 0, & f(x) \le \inf(f). \end{cases} \tag{11}$$

Relative to the forward indicator can be described by

$$\mu(x) = \begin{cases} 1, & f(x) \le \mathrm{suf}(f), \\ \dfrac{\mathrm{suf}(f) - f(x)}{\mathrm{suf}(f) - \inf(f)}, & \inf(f) \le f(x) < \mathrm{suf}(f), \\ 0, & \mathrm{suf}(f) \le f(x), \end{cases} \tag{12}$$

where Sup(f) and sup(f) are the upper and lower bounds of hair $f(x)$, respectively. Similarly, the evaluation vectors R_1, R_2, and R_3 for every single factor can be obtained by equations (11) and (12).

Through a comprehensive multifactor evaluation of one-year low-carbon economic development in Guangzhou, its comprehensive score is obtained. Figure 4 highlights the

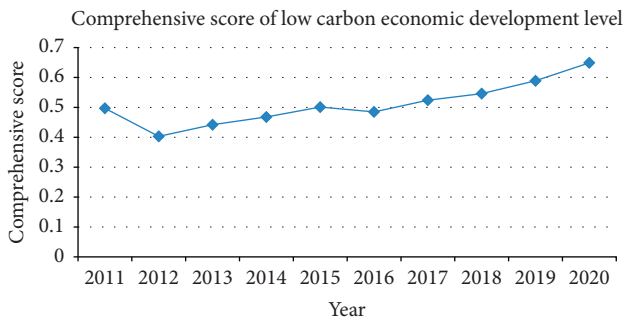

Figure 4: Comprehensive score of Guangzhou's low-carbon economic development level.

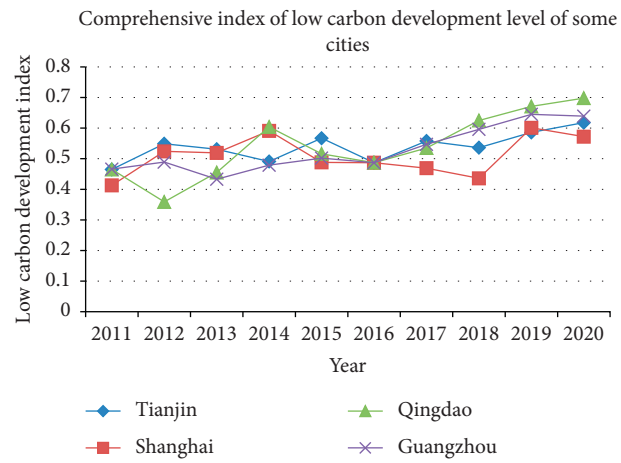

Figure 5: Comprehensive index trend map of urban low-carbon economic development level.

trend map of a comprehensive score of Guangzhou's low-carbon economic development level.

From Figure 4, we can see that the overall low-carbon economic development index of Guangzhou shows an increasing trend from 2011 to 2020, and the overall level of low-carbon economic development is also increasing. Except for the inflection points in 2013 and 2016, significant growth has occurred in the remaining years. The UK took the lead in introducing a low-carbon economy in 2002. Since 2008, the boom in the development of a low-carbon economy has continued. Figures 5–7 also demonstrate that the low-carbon development of Guangzhou during 2010–2016 displays considerable fluctuation, particularly during 2016–2020, which is strongly connected to energy saving and emission reduction, as well as the robust growth of Guangzhou's low-carbon economy.

5.2. Analysis Results Compared with Other Coastal Cities. Through comparison, three representative coastal cities, Tianjin, Shanghai, and Qingdao, are comprehensively analyzed by using the same index and calculation method. Guangzhou is selected as one of the four most developed cities in the coastal area because they are important trade ports in the country. Under similar economic development patterns, there are also problems such as energy shortage and environmental pollution. The overall scores of the four cities are shown in Figure 5.

From Figure 5, we can see that the low-carbon economic development of the four coastal cities shows a fluctuating growth trend. Guangzhou has a strong postdevelopment advantage in low-carbon economic development. After 2016, its development speed gradually surpasses Shanghai and Tianjin and is on the same level as Qingdao's comprehensive score. This shows that the low-carbon economic development of Guangzhou in recent years is on the track of healthy development and has a trend of continuous upward development.

In order to better evaluate the advantages and disadvantages of Guangzhou's development, the economic, technological, social, and environmental system scores of each city are analyzed, and a comparison chart of each system score is obtained.

5.2.1. Comparison Map of Economic System Scores among Cities. The comparison chart of each system score is shown in Figure 6. From this figure, it can be seen that the economic system score of Guangzhou shows a significant positive upward trend compared with the economic system score of the other three cities. Tianjin was ranked second before 2014, and there was an extraordinary growth in 2015, which was attributed to the completion and operation of a significant number of infrastructure projects in Guangzhou in 2014. However, the rate of economic development has been dropping since 2016, due to the distinctive moment wherein Guangzhou has become a new tourist destination. However, the rate of economic development has been dropping since 2016, due to the distinctive moment wherein Guangzhou has become a new tourist destination.

5.2.2. Comparison of Scores of Science and Technology Systems among Cities. Figure 7 shows the scientific and technical system scores. From this figure, it is clear that Guangzhou's degree of scientific and technological development has been steadily rising, from a backward position before 2017 to first place in 2017 and has been there ever since. Guangzhou's scientific and technological advancement plays a significant role in promoting the development of its low-carbon economy in this period of fast scientific and technological development.

5.2.3. Comparison of Scores of Social and Environmental Systems among Cities. From Figure 8, we can see that the social system of Guangzhou is generally stable, while the other three cities continue to decline. This demonstrates that Guangzhou still has a significant edge in terms of the living environment, but we must be vigilant in light of the continuous decline in recent years.

The ecosystem of Figure 9 is evaluated. The results show that the score of ecological environment quality in Guangzhou has been declining continuously, and the other

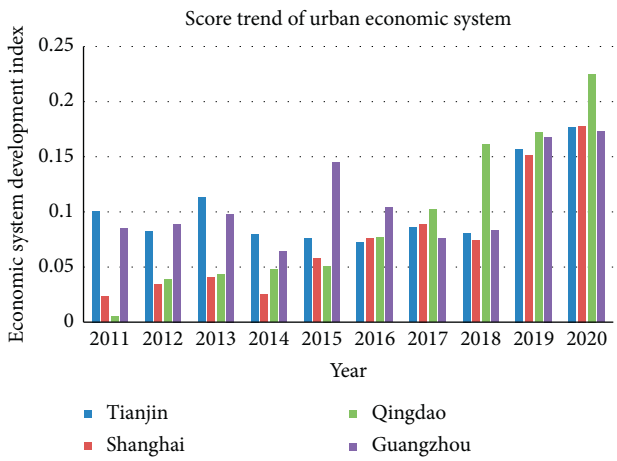

Figure 6: Trend maps of the score of economic system in some cities.

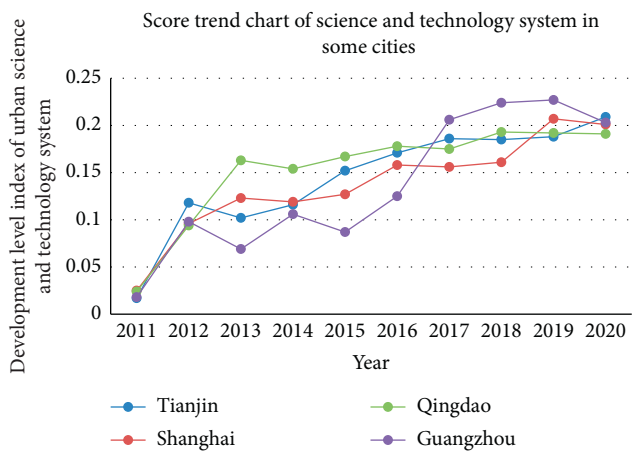

Figure 7: Score trend map of science and technology systems in some cities.

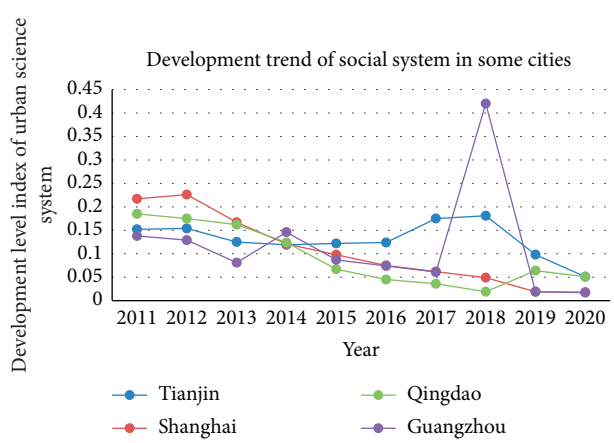

Figure 8: Trend map of social system score in some cities.

three cities have shown fluctuating declines, indicating that the ecological environment problems in the development of Guangzhou are becoming more and more serious.

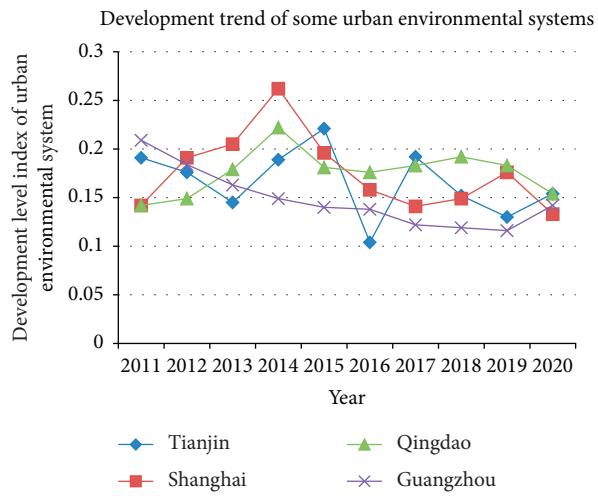

Figure 9: Score trend of some urban environmental systems.

6. Conclusions

Dealing with the significant strain generated by climate change, low-carbon cities are becoming a development trend of urban ecosystems in China, notably in Guangzhou. It is essential to consider the levels of urban low-carbon growth to promote the establishment of low-carbon cities. Therefore, one must evaluate the executive impact to guarantee that low-carbon building is a constant emphasis and detect current difficulties and offer suitable legislation. To solve these issues, this study proposes an assessment indicator system for urban low-carbon development levels, energy structure and use effectiveness, living usage, and growth environment. In addition, this paper analyses and examines the important components driving the establishment of a low-carbon economy in Guangzhou. It provides the present situation of low growth in Guangzhou and the obstacles it confronts. Furthermore, the structural model is fitted and updated depending on the data reliability analysis and testing using the data analysis application LISREL 8.80. Lastly, it creates model data for measuring and evaluating Guangzhou's low-carbon economic growth level.

Data Availability

All the data used to support the findings of the study are available within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest for the publication of this paper.

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Research Article

A Human Motion Function Rehabilitation Monitoring System Based on Data Mining

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Human motion interaction technologies have evolved to a new level with the development of traditional reality technology as science and technology have developed. Fully interactive and human motion interaction technologies are becoming more common in fields such as medical rehabilitation and military simulations. Human motion is at the heart of all activity, and motion analysis and human motion are critical theoretical disciplines. Identification is based on behavior and motion in human motion, with attributes such as effectiveness, intelligence, potent interaction, and rich expression data. When studying human movement, many researchers now prefer this method. However, this study was conducted with insufficient suggestions for real-time human motion function assessment, rehabilitation, and improvement. The development of an information monitoring system for human motion function rehabilitation can be used to evaluate the efficacy of patient rehabilitation training. A human motion function rehabilitation monitoring system is created using an effective and thorough design methodology. The system is made up of the rehabilitation monitoring terminal, the human motion function monitoring module, and the medical center monitoring system. Therefore, the motion-based data mining technique is better for the human motion function rehabilitation monitoring system. The normalized proportion of motion features will assist in the creation of a database for human motion mining. The nonlinear classification function is used in this paper to scientifically categorize human motion features to implement data mining techniques for monitoring human motion function rehabilitation. The effectiveness of patient rehabilitation is significantly increased by the use of a human motion-based rehabilitation monitoring system.

1. Introduction

A patient may be required to complete a comprehensive and important physical rehabilitation program to regain their prior strength, flexibility, and fitness after some kind of illness, injury, or surgery. The primary goal is to evaluate and optimize the patients' lifetime capabilities and motion qualities, and it is standard procedure in this environment to continuously monitor the patients' movements. In rehabilitation facilities, traditional physiotherapy-based treatments are frequently used; these treatments indicate the need for qualified professionals and their invaluable competence [1]. The standardized, objective data necessary to fairly assess patients' accomplishments might not be present in these treatments. Since the 1980s, there has been an increase in patients with motor function problems, which has made human motion tracking for rehabilitation a popular research topic. Humans must move their bodies in order to survive, and healthy people move their bodies frequently, while sick people move their bodies much less frequently. Stroke, one of the leading causes of disability in the world, frequently results in a limb or limbs losing all or some of their performance as a result of motor dysfunction [2]. In recent years, neurorehabilitation medicine research has advanced gradually, and the general public has assumed that damaged human motor function could be partially restored. Using scientific rehabilitation techniques could result in complete paralysis, low stamina, loss of motor control, or muscle weakness. On the other hand, looking for an effective rehabilitation treatment method to assist the patient in regaining human motor function will be counterproductive. It not only helps to improve the standard of

living for patients but also reduces the burden on their families and society [3]. The overarching functional design scheme of the human motor function rehabilitation monitoring system clarifies the particular design plan of the subsystem. The monitoring terminal for rehabilitation, the human motor function monitoring module, and the monitoring system for the medical facility are also included in the composition.

Through trials, information on plantar pressure under different motion modes and details on the current gait were acquired. Li et al. are now using fuzzy mathematics theory to characterize human behavior. The significant gait events, such as the contact of the leg and foot, were identified using dynamic baseline monitoring. The screening windows are used to filter the repeated individual monitoring over a specified period for the error monitoring of vital gait events, significantly improving identification accuracy and supplying essential gait data for the categorization of movement patterns. The viability and effectiveness of the fuzzy theory application for human motion identification are established by performing similarities comparisons on each pattern, the relevant levels of motion extraction features, and the relevant levels of motion pattern recognition. Artificial intelligence is expected to provide processing approaches and research projects to meet future demand [4]. Villanueva et al. describe a wearable multisensor system for monitoring human movement in stroke rehabilitation. It is composed of several teeny-tiny modules that can wirelessly connect and transmit motion-related data to an acquisition device. It is beneficial for human motion collecting and monitoring, which is required for activities such as activity detection, measuring physical and athletic performance, and rehabilitation, and according to the results of a series of experiments, we evaluated its performance in real-world environments [5]. Banaee et al. investigated the most cutting-edge methods and algorithms for interpreting data from smart technology used for physiologic monitoring of vital signs in healthcare services in a recent publication. The paper provides an overview of the more popular data mining applications, such as intrusion detection systems, prediction, and decision making, with an emphasis on continuous time-series observations. The study also discusses the suitability of specific data mining and machine learning algorithms used to evaluate the physiological data and provides an overview of the features of the data sets used in experimental verification. Several key challenges for data mining approaches in health monitoring systems have been identified based on this literature review [6].

Rehabilitation training is a method of brain plasticity rehabilitation treatment, and the findings of modern neurorehabilitation medicine and associated studies show that. For human motor dysfunction caused by problems such as stroke, adopting scientific rehabilitation training treatment modalities can effectively recover the damaged human motor function to a corresponding extent. Rehabilitation physicians must conduct a real-time objective evaluation of the effect of rehabilitation training on patients during the rehabilitation training process. Accurately assess motor recovery ability as well as training participation, and effectively adjust the feedback scheme of rehabilitation training based on the evaluation results. The efficiency of rehabilitation training is improved, and the effect of rehabilitation is maximized. The process of analyzing and extracting information from large datasets is called data mining. It is important to use a data mining method to monitor the rehabilitation training process for patients with human motor dysfunction and deep understanding. The effect of rehabilitation training under objective data is significant in terms of improving the effectiveness of rehabilitation treatment for patients. The overall functional design scheme of the human motor function rehabilitation monitoring system clarifies the subsystem's specific design scheme. The rehabilitation monitoring terminal, the human motor function monitoring module, and the medical center monitoring system are all part of this system.

The innovation of this paper is as follows:

(i) Firstly, the data mining method based on motor features was applied to the human motor function rehabilitation monitoring system, and human motor function rehabilitation monitoring data mining was realized

(ii) Secondly, in comparison with the traditional monitoring system of human motor function rehabilitation, the data mining-based monitoring system of human motor function rehabilitation is presented

(iii) Finally, overall performance improved both the real-time performance of the human motor function rehabilitation monitoring system and the effect of patient rehabilitation training

The remainder of the paper is structured logically as follows: Section 2 shows related work; Section 3 represents the human motion function rehabilitation monitoring system based on data mining; Section 4 demonstrates the human motion function rehabilitation monitoring method based on motion characteristics, and Section 5 shows the experimental results and analysis. Finally, Section 6 concluded this work.

2. Related Work

In the early years, relevant researchers at home and abroad began to conduct in-depth research on human physiological parameters and rehabilitation monitoring, and they achieved some research results through their efforts. Li et al. proposed a monitoring system for human remote rehabilitation training, which provides a remote rehabilitation training monitoring platform for patients in rehabilitation. The terminal-controlled module processor is a 32-bit STMicroelectronics (STM32) integrated circuit that controls data acquisition, processing, and transmission. Complete the communication between the acquisition device and the cloud server during the rehabilitation process using the Message Queuing Telemetry Transport (MQTT) protocol. Analyze the time-frequency domain of electromyography (EMG) signal to calculate the specific situation of muscle

strength and muscle fatigue and calculate the activity of human joints from the signal of attitude sensor for rehabilitation evaluation of rehabilitation training. To complete the interaction between the browser and the cloud server, use the Tomcat server to display the patient's rehabilitation data on the web page. However, remote rehabilitation training monitoring, uploading, and the mointoring system need help to discharge stroke patients for rehabilitation treatment and early recurrence warnings. A multifunctional human motor function rehabilitation monitoring system was created, which included human physiological signals, treatment, and data analysis. The therapeutic device uses transcranial direct current stimulation technology to accurately output constant and direct current. The patient's heart rate and other pertinent data are then routinely monitored by the intelligent bracelet, which is created as an adjunct rehabilitation monitoring device. Send the rehabilitation data to the mobile phone via Bluetooth, and then use the mobile phone to summarize the treatment records and vital signs data before uploading the summarized data to the cloud for in-depth analysis. It is specifically used to adjust the rehabilitation treatment plan or for early warning of stroke recurrence. The development results show that the monitoring system can not only meet the needs of human motor function rehabilitation treatment but also realize the interconnection between cloud and equipment. The system can provide effective solutions for personalized treatment of stroke, recurrence early warning, and database, but the system has the problem of high cost [7]. Yang et al. describe a human rehabilitation monitoring system based on an embedded controller designed to meet the needs of human postoperative recovery training. A multifunction human rehabilitation training mode, movement posture, EMG signal acquisition, and safety protection are realized. The training process is identified and analyzed by using the random forest machine learning method and linear regression method. The results show that the designed human rehabilitation control and monitoring system can use Android for portable control. To complete the intelligent analysis of the rehabilitation training process, use the monitoring signals in the training process. The random forest method has advantages over the linear regression method in human motion recognition, but the rehabilitation effect of this method is poor [8]. Guan et al. propose a human rehabilitation movement monitoring method based on human posture information to control rehabilitation training for patients with human motor dysfunction after surgery. It is a data collection system for human motion data that is customized to the structural characteristics and functional requirements of rehabilitated patients. The kinematic model of human rehabilitation is built, and a behavior information collection system for human posture is established on the rehabilitation platform. The software evaluates the expected follow-up speed of rehabilitation based on the behavior change information representing human posture obtained from the displacement analysis sensor. To reduce the error generated, the tracking controller is designed using the fuzzy control method and a simulation experiment. However, this method has the problem of poor real-time performance in the process of patients' real-time tracking movement and realization of the following effect of rehabilitation on patients' motion posture [9].

3. Human Motion Function Rehabilitation Monitoring System Based on Data Mining

Figure 1 depicts the overall framework of the human motor function rehabilitation monitoring system. The data mining-based human motion function rehabilitation monitoring system is primarily composed of a large number of collection nodes for physiological parameters worn by patients. A self-organized wireless network is established between the nodes, and the physiological parameter signals are transmitted to the convergence node of the wireless network through the Zonal Intercommunication Global (ZigBee) protocol. ZigBee is a low-power, low-data-rate M2M (machine-to-machine) wireless network and Internet-of-Things (IoT). The ZigBee protocol is based on IEEE 802.15.4. A ZigBee network is made up of several full-function devices (FFD) that gather data from nearby reduced-function devices (RFD).

The local monitoring system consists of embedded portable devices connected to a wireless network, with a sink node collecting physiological data. The main purpose of the medical center's monitoring system is to create a database of multiple physiological parameters of patients and extract them. Identify patients' physiological and psychological states and evaluate patients' rehabilitation effects in real time [10, 11].

3.1. Design of Rehabilitation Monitoring Terminal System. Figure 2 shows the composition of the rehabilitation monitoring terminal system. The physiological parameter acquisition module and the data transmission module are included in the design of the rehabilitation monitoring terminal system. The physiological parameter acquisition module is a multiparameter physiological module that measures and monitors heart rate, noninvasive blood pressure, respiration, oxygen saturation, temperature, and Enteric Coated (EC). The acquisition module of physiological parameters must install the node in the appropriate position of the patient's body to collect the patient's human physiological signals. The selection of physiological signals is mainly divided into collecting electromyography (EMG), electrocardiography (ECG), pulse, and triaxial acceleration. In the node design of hardware, medical sensors and methods for specific physiological signals and signal conditioning circuits such as filtering are composed [12, 13].

The rehabilitation data transmission module in the hardware platform makes use of data communication between network nodes and the iris node. The integrated processing chip of the node is the controller and the radio-frequency (RF) chip is the wireless transceiver. The tiny operating system and network cable network routing protocol design are used in the software implementation. The designed networking application is added to the control chip of each node, which can realize the rehabilitation data transmission between wireless nodes, as well as some characteristics such as low-power consumption, load balancing, and robustness.

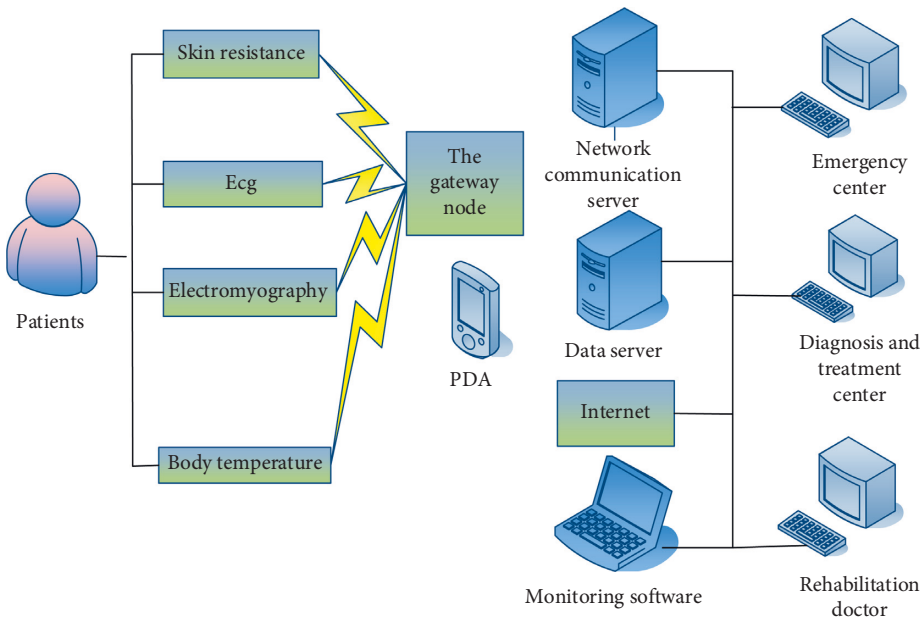

Figure 1: Overall frame diagram of the rehabilitation monitoring system.

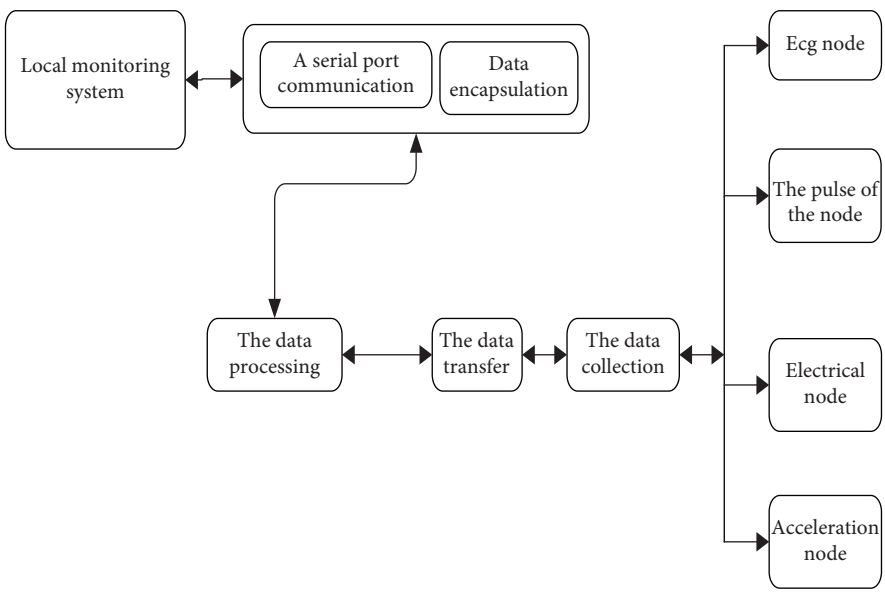

Figure 2: Rehabilitation monitoring terminal system composition diagram.

3.2. Human Motor Function Rehabilitation Monitoring Module. Figure 3 shows the composition of human motor function rehabilitation monitoring. The unit hardware of the monitoring module is an embedded operating system using the processor core board of the Advanced RISC Machine (ARM9). The software realizes the terminal node data collection, processing, and storage of rehabilitation data and provides the user interface for images for patients. It uploads the collected rehabilitation training data to the medical monitoring center. The local monitoring system module specifically includes embedded transplantation and multiple modules such as data acquisition, data storage, display unit, and network communication [14, 15].

The rehabilitation training data acquisition module serves as the interface between the network node and the ARM processor, and it must analyze various physiological data types. The node collects data using the serial communication protocol, and data processing is the core module in the local monitoring system. It must process and store various physiological signals collected from patients, as well as various control instructions received from the display unit, which is a designed monitoring interface. In the development environment, a graphical interface primarily displays the collected human physiological signals of patients in the form of a real-time dynamic curve. The network communication module is a bridge connecting the local monitoring system and the

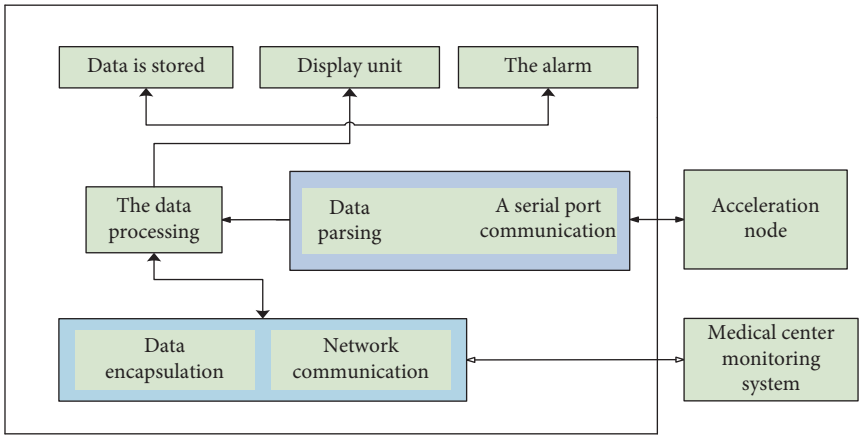

Figure 3: Local monitoring system composition diagram.

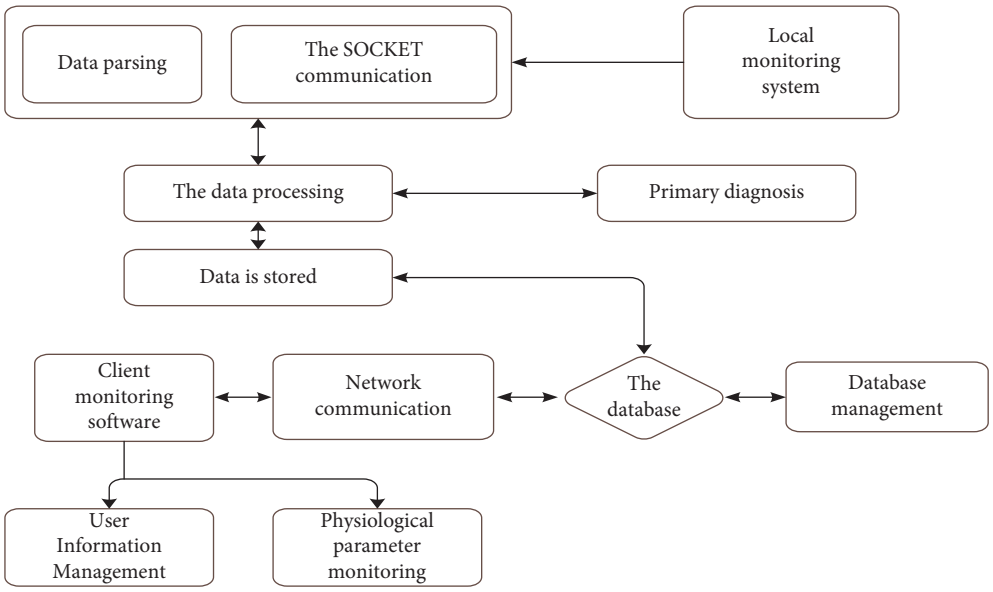

Figure 4: Composition of the medical center monitoring system.

monitoring system of the medical center. The module adopts Transmission Control Protocol (TCP) and realizes the sending and receiving of rehabilitation data through the socket communication model design.

3.3. Medical Center Monitoring System. Figure 4 shows the composition of the monitoring system of the medical center. The medical center's monitoring system is built on the Client/Server framework, which consists of monitoring software for both the server and the client. The server realizes the communication with the local monitoring system and client monitoring software, as well as the storage and processing of rehabilitation data. It specifically includes multiple modules such as network communication, user information management, and ecological parameter monitoring [16, 17].

The communication server is built based on the TCP, connected with a socket, receives the link from the online local monitoring system and the analysis data packet of the communication protocol, and stores it in the database. The data processing module includes data analysis, preliminary diagnosis, data storage, and so on. The physiological parameters are mined by a data mining algorithm, and the physiological features are extracted and preliminarily diagnosed. The processed data is stored in the database for query and call by the monitoring software of the client. User information management mainly saves the patient's personal information and physiological data. The monitoring module of physiological parameters uses the call database to obtain the physiological data of patients and displays electrocardiogram (ECG), muscle point, pulse, and other signals in the form of a waveform curve. It is also capable of monitoring physiological parameters. It will provide an early warning if a patient's physiological parameters exceed the set threshold [18, 19].

3.4. Data Frame. The data frame defines the format of the data packet when transmitting rehabilitation data, including the destination node, source node, and the length of the data packet. The specific format of the data frame is shown in Table 1.

4. Human Motion Function Rehabilitation Monitoring Method Based on Motion Characteristics

There is a close relationship between human motion characteristics and human actions. It is necessary to analyze the importance of human motion characteristics from the direction of human motion. We will talk about the characteristic threshold of patients' human motion.

4.1. Motion Feature Extraction. Some of the patient's human motion features are deleted based on the threshold to obtain the real motion behavior-related features. In general, the motion feature weight coefficient of the patient must be calculated using parameters such as intensity and amplitude. The patient's human behavior movements are described to convey the significance of the patient's human motion feature. Suppose M_j is the intensity parameter of the patient's human motion characteristics, M_0 is the motion amplitude parameter of human motion characteristics, and Q is the number of human motion characteristics. Calculate the threshold change parameter:

$$S_{M\ DS} = \frac{M_1 + M_2}{QT}. \tag{1}$$

In the process of patients' rehabilitation training, the importance of motor function intensity parameters is higher than that of motion amplitude parameters. Therefore, they must be given different weight coefficients [20, 21]. By setting the weight coefficient proportion in the golden section mode, formula (1) can be transformed to obtain

$$S_{M\ DS} = \frac{2\left(0.618M_j + 0.382M_0\right)}{M_j + M_0}. \tag{2}$$

In formula (2), $S_{M\ DS}$ represents the parameter of threshold change, which can map the patient rehabilitation data to the range of (0, 1). The mapping formula is represented by

$$x = 1 - \exp\left(S_{MDS}\right). \tag{3}$$

In formula (3), χ represents the influence of the threshold change parameters on the threshold. Assuming that the duration of the patient's human motion is U_e and the total duration of human motion is U_s, the characteristics of the motion time are smoothed to eliminate the error, and the threshold can be expressed by

$$\varepsilon = \left(\beta U_e + U_s\right)(1 + \chi). \tag{4}$$

If the characteristic parameter of human motion in the process of rehabilitation is greater than the threshold, it can be judged that the feature is the real motion feature of the human body.

4.2. Optimizing the Data Mining Process of Human Motor Function Rehabilitation. Through the nonlinear classification function, the data mining of human motion function rehabilitation monitoring can be realized based on extracting the human motion characteristics of patients. Let the set composed of human motion characteristics of patients be described by $\left\{y_j, z_j\right\}$, $z_j \in (1, -1)$, and the classification function be expressed by

$$g(y) = x \bullet y + c. \tag{5}$$

If the classification interval of patient rehabilitation monitoring data is the maximum, the requirements of the following formula must be met:

$$z_j\left[(x \bullet y) + c - 1\right] \geq 0, \quad j = 1, 2, \ldots, p. \tag{6}$$

The solution of the optimal classification function can be expressed by

$$\gamma(x) = \frac{1}{2}x = \frac{1}{2}(x \bullet x). \tag{7}$$

The Lagrange factor is introduced into the classification function of patients' human motor function rehabilitation monitoring, and the function represented by the following formula can be obtained:

$$M(x, c, b) = \frac{1}{2}(x \bullet x) - \sum^{j=1}_{p} b_j\left\{z_j\left[\left[(x \bullet y) + c\right] - 1\right]\right\}. \tag{8}$$

It is concluded that the classification function of human motion characteristics in the process of patient rehabilitation monitoring can be expressed as

$$g(y) = \operatorname{sgn}\left\{\sum^{j=1}_{p} b_j^* z_j\left(y_j \bullet y\right) + c^*\right\}. \tag{9}$$

According to the above classification function of patients' human motion features, patients' human motion features can be divided into different categories of motion feature sets [22, 23]. According to these characteristics, the motor function data mining process in the process of patient rehabilitation monitoring can be described by

$$g(y) = \operatorname{sgn}\left\{\sum^{j=1}_{p} b_j^* \exp\left(\frac{\left|y - y_j\right|^2}{\varepsilon^2}\right) + c^*\right\}. \tag{10}$$

In the process of human motion mining of patients' human motion function rehabilitation monitoring data, the most important problem is how to select scientific parameters.

Table 1: Data frame format of the terminal node.

The field names	Length (bytes)
Tiny OS Header	6
Xmesh Header	8
Xsensor Header	5
Data Payload	17
CRC	2

If the parameters are not scientific, it will have a great impact on the accuracy of human motion mining results [24, 25]. Therefore, we must optimize the penalty coefficient and the width of the kernel function through the radial basis kernel function. According to the optimized results, the optimal rehabilitation effect of human motor function is obtained, and the research on human motor function rehabilitation monitoring system based on data mining is completed.

5. Experimental Result and Analysis

Experiment verification is used to demonstrate the performance of the human motion function rehabilitation monitoring system based on data mining. Table 2 shows the experimental environment of the rehabilitation monitoring system.

Figure 5 shows the mining error comparison between the human motion function rehabilitation monitoring method based on motion feature data mining proposed in this paper and the human motion function rehabilitation monitoring method based on traditional data mining.

Figure 5 shows that at the start of the experiment, the mining error of the traditional data mining human motion function rehabilitation monitoring method was 29%. However, as the amount of data increases, the mining error gradually increases, reaching 42% before beginning to decline. Traditional data mining has a high overall error rate, resulting in poor data mining accuracy. At the start of the experiment, the mining error of the human motion function rehabilitation monitoring method based on motion features proposed in this paper was low. Although data increases slightly, the overall increase does not exceed 10%. This shows that the mining accuracy of the method proposed in this paper is high enough to effectively mine important patient information. They assist doctors in understanding the rehabilitation situations of patients so they can adjust the rehabilitation scheme for patients and improve the rehabilitation effect of patients during the rehabilitation monitoring process. The mining times of the motion feature data mining-based human motion function rehabilitation monitoring method and the traditional data mining-based human motion function rehabilitation monitoring method are compared in Table 3.

It can be seen from Table 3 that the time of traditional data mining methods in mining human motor function rehabilitation data is 47 s while the time required to mine human motor function rehabilitation data using the action feature data mining method proposed in this paper is 15 s. This shows how using the method outlined in this paper can effectively increase the effectiveness of data mining and assist medical professionals in quickly analyzing patient rehabilitation monitoring data. The human motion function rehabilitation monitoring system of the method suggested in this paper and the human motion function rehabilitation monitoring system are compared in real time in Figure 6.

The analysis of Figure 6 shows that the real-time performance of the human motor function rehabilitation monitoring system of the method proposed in the document is not high as a whole [3]. The real-time performance gradually increases with the increase of data at the beginning of the experiment. The real-time performance of the proposed human motion function rehabilitation monitoring system in the document gradually improves, but then declines when the experimental data reaches 1000 [4]. Throughout the experiment, the real-time performance of the human motion function rehabilitation monitoring system proposed in this paper was excellent. This is because this system uses data mining to monitor the rehabilitation training process for patients with human motion dysfunction. To understand the effect of rehabilitation training on patients in real time, we must first master the effect of rehabilitation training under objective data. The human motion function rehabilitation monitoring system of the method suggested in this paper and the human motion function rehabilitation monitoring system are compared in terms of overall performance in Figure 7.

Figure 7 shows that the overall performance of the human motor function rehabilitation monitoring system was better at the start of the experiment, but began to deteriorate as the data volume increased. At the start of the experiment, the overall performance of the human motor function rehabilitation monitoring system was slightly lower. This paper presented the overall performance that improved gradually as experimental data increased, but system performance was slightly significantly underrepresented in comparison with the rehabilitation monitoring system. The more stable overall performance of the data mining-based monitoring system for human motor function rehabilitation presented in this paper

Table 2: Experimental environment of the rehabilitation monitoring system.

Type	Experimental environment
The operating system	Windows 7 (64 bits)
Development platform	Unity3D, Visual Studio (2017)
Development of language	C++
Memory	4 GB (gigabyte)

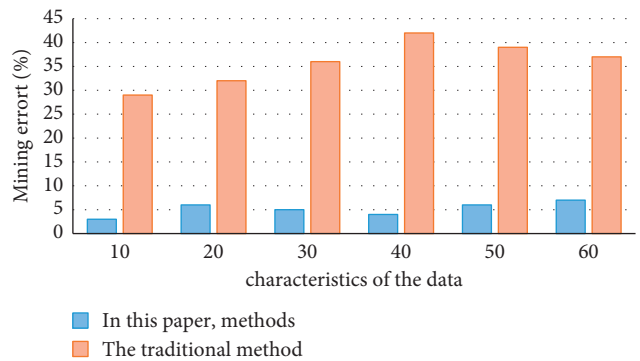

Figure 5: Comparison of mining errors of different mining methods.

Table 3: Comparison of mining time of different mining methods.

Different methods	Mining time (s)
Proposed methods	15
Traditional method	47

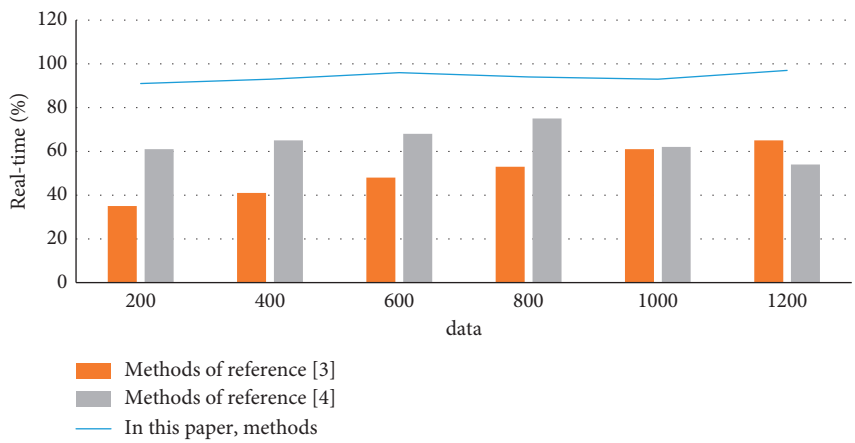

Figure 6: Comparison of the real-time performance of rehabilitation monitoring systems under different methods.

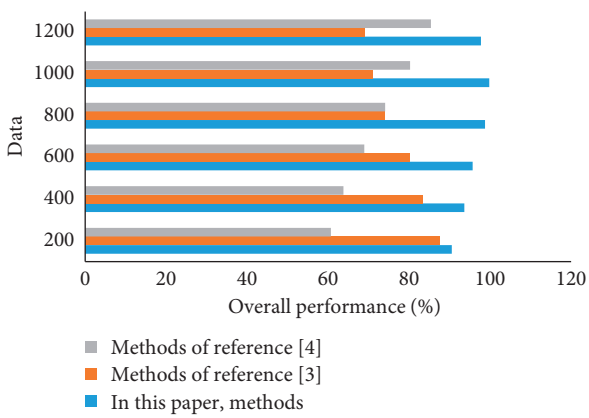

Figure 7: Overall performance comparison of rehabilitation monitoring systems under different methods.

is because the data mining method presented in this paper classifies human motor features through a nonlinear classification function, which enables the mining of human motor function rehabilitation monitoring.

6. Conclusions

Human motion recognition research is expected to show that motion recognition is improved by human motion recognition. Human motion recognition science is progressing, and new technologies to improve our daily lives are emerging. This paper presented the design of a data-mining monitoring system for the restoration of human motor function. As the number of people suffering from human motor dysfunction as a result of illnesses such as stroke rises, this can be used in rehabilitation therapy. Relevant studies have shown that the use of scientific rehabilitation training can restore the damaged human motor function of patients to a great extent. In the process of rehabilitation training, rehabilitation doctors should monitor the physiological information of patients in real time. This paper uses data mining techniques to design and implement a human motion function rehabilitation monitoring system to meet this demand. This system enables timely evaluation of the training effect of patients' rehabilitation as well as timely modification of the rehabilitation plan. The system processes and analyzes the physiological information of patients to improve the effectiveness of rehabilitation training. The results of the experiments show that the human motion function rehabilitation monitoring system suggested in this research has good overall performance. This significantly improves the system's real-time performance and patient rehabilitation effectiveness. Although the system works well, it will be improved to increase battery life, reduce sensor size and weight, and improve the temporal synchronization of various sensor signals. The proposed system will be a component of a networked rehabilitation system that will also include sensors and rehabilitation robotics [26].

Data Availability

All the data are available in this paper as part of the publication.

Conflicts of Interest

The author has no conflicts of interest in the publication of this paper.

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Research Article

Designing an Accounting Information Management System Using Big Data and Cloud Technology

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With the rapid development of science and technology pushing people into the information age, the appearance of information technology is a major change for the accounting industry, which will redefine the traditional accounting profession. The new management techniques and concepts also gradually change the traditional accounting working mode by promoting the development of accounting professionals from traditional accounting to accounting information. In recent years, cybercrime and attacking information system vulnerability have occurred frequently. This study utilizes the model and technology in the design of an accounting information management system by simply explaining the idea of cloud technology and examining its logical structure of cloud technology. After that, it designs the cloud platform architecture of the accounting information management system (AIMS) by building the SaaS model. It defines the distributed storage mode of the cloud platform and tests the cluster performance of the system after completing the system design and construction to judge the application effect of the system. Finally, the system operation time, local rows of data, and load balancing are tested experimentally. These results demonstrate that the response relationships of distinct tasks are modified higher than TeraSort, TeraSort higher than Inquiry, and response time is proportional to the amount of Reduce slots when input tasks are the same. The analysis shows that the large data cloud platform used in this paper has high operational efficiency, acceleration rate, and task execution rate.

1. Introduction

Currently, the convergence of artificial intelligence and machine learning has created computers as a significant tool for human everyday productivity and life. These innovations have played a key role, particularly in the field of data processing, where they can not only store massive amounts of data but also do statistics and analytics on them until further investigation of the practical value of data sources. Since the introduction of application databases, people have handled information much more easily and accurately. As a result, data sources have grown increasingly significant in the domains of business, administration, and investigation. With the maturation of computer technology and the adoption of computers since the beginning of the 21st millennium, many areas of life have created more data than possible while achieving enormous progress. Due to the above, many use the term "info explosion" to characterize the exponential increase of data. The abundance of information has also caused numerous challenges in people's everyday activities and lives, particularly those relating to how to access relevant information effectively. Only through understanding market dynamics and user demands and that offering products and services that satisfy market opportunities to customers can contemporary businesses prosper and grow. In a highly competitive market, firms must seek out meaningful information to make maximum utilization of data sources for user monitoring, market research, and analytical decision-making. In the procedure of extracting useable information, irrelevant information has become a headache for businesses, affecting not only the efficiency of information processing but also playing a deceptive role. As a result, data-gathering technology has great value and also builds strong future growth [1].

Since financial management is linked to the survival and development of businesses, which is considered very

important in enterprise management. In addition, it is also a significant criterion for assessing the operational state of businesses. With the fast growth of network technology and information technology, more and more businesses are focusing on financial management informationization [2]. The financial management department is the most important aspect of the enterprise's business management. The finance team will synthesize the audit views of all of the enterprise's businesses, and the financial department employees will finish the unified accounting. Therefore, it is urgent to improve enterprise financial information management. This paper uses big data cloud technology to design an accounting information management system [3]. Big data cloud technology uses Internet technology to provide people with various computing resources. Its structure mainly has three levels including platform, resources, and applications. It uses shared resource storage and resource invocation to improve object availability. In an era of fast advances in data processing technologies, organizations are no longer happy with shortcuts like randomized research and sample analysis. They require a significant volume of big-scale data from many domains, as well as an accounting management information system based on a cloud-based accounting framework. The ability to effectively construct an AMIS implementation framework based on cloud accounting has grown dependent on the ability to access huge data. Enabling the collection of big data inside the big data environment is becoming a very significant problem in contemporary academic and industrial communities.

By examining the current studies, it is discovered that the majority of current AIMS construction research concentrates on the conventional Internet environment, whereas AIMS design research integrating big data and cloud accounting is very sparse. Indeed, as big data technology advances, it plays an essential role in corporate management and financial decision-making, and the successful use of big data capabilities is inextricably linked to AIS based on cloud accounting. As a result, this study demonstrates the AIMS framework based on cloud accounting in the era of big data. It elaborates on the responsibility of each component in the framework based on analyzing whether cloud accounting can successfully use accounting information system applications. In addition to the above, this paper uses big data cloud technology to maximize and efficiently integrate computing resources and improve system informatization and intelligence through an in-depth learning network.

The main innovations in the research phase of this paper are as follows: (1) Computing, the logical structure of cloud technology, and the RBM energy model based on a learning algorithm. This algorithm and theory serve as an important basis for the design and development of this system. (2) Based on the big data cloud technology, the overall architecture of the accounting information management system is designed, the SaaS model of the system is built, and the distributed storage method is used to save the enterprise financial data to realize the accounting information office [4]. Figure 1 highlights the structure of this paper.

The rest of this article consists of 5 sections: Section 2 is based on related work of national and international scholars, Section 3 presents an overview of big data cloud technology for Accounting Information Management System (AIMS), and Section 4 demonstrates the design of AIMS based on Big Data Cloud Technology, the testing and simulation of the proposed system highlighted in Section 5, finally, this work is concluded in Section 6 of the paper.

2. Related Work

With the rapid increase of cloud data, cloud technology has become a new research hotspot at home and abroad. Subramanian deeply studies the cloud security issues of the three entities of data owners, cloud service providers, and cloud users at the levels of computing, communication, service level agreements, and data. The scholars in [5] empirically evaluated the practicality of financial information and accounting data in enterprise strategic management and changed the traditional accounting model based on the management information support system. They tried to expand the accounting time range and improved the budgeting process and the ability to analyze the background. The early work of [6] analyzed the role of society, environment, and management in the accounting system, and selected ASG data as the main tool to test sustainable development. In this regard, the work of [7] pointed out that the company's dynamic capability, continuously changing conditions, and environment all affect the effectiveness of the accounting management system, resulting in changes in the accounting management information system. The authors of [8] put forward the adjustment strategy of an effective management accounting information system. Accounting information has been examined using LISRELL software and a structural equation model based on collaborative variance as vital financial data for enterprise managers to comprehend business situations and build development plans. The findings indicate that successful corporate application software has a direct impact on the quality of accounting information.

Keeping the above, the work of [9] proposed to apply the cloud computing model in the accounting information management of small enterprises. It improves system operating efficiency by utilizing cloud distributed processing, cloud cooperative design, cloud simulation, and other technologies. The scholars of [10] proposed accounting information management based on Financial Shared Services, which can help to lower the cost of financial management, enhance the quality of financial services, and increase overall management efficiency. It is a new management model. Before establishing a financial shared information system, enterprises should first determine various influencing factors of accounting information management to ensure the safety of enterprise financial data and the feasibility of accounting information management. The author in [11] has used the financial accounting information management system in China's chemical enterprises to completely change the traditional management mode by applying information technology in financial accounting management. It greatly enhances business management efficiency by fully utilizing information technology in

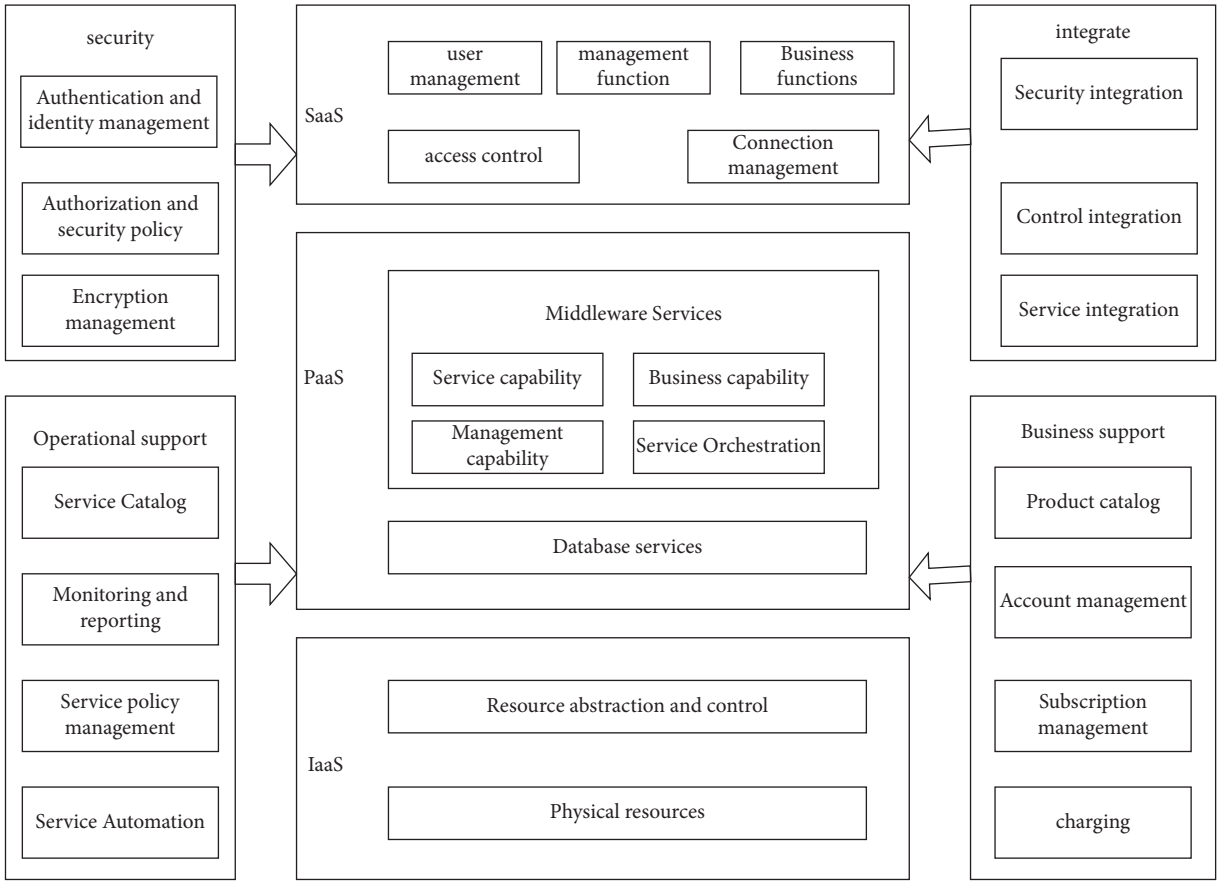

Figure 1: Logical structure of cloud technology.

financial accounting management and increasing the application value of information technology. This study utilizes the model and technology in the design of an accounting information management system by simply explaining the idea of cloud technology and examining its logical structure of cloud technology.

3. Overview of Big Bata Cloud for Accounting Management Information System (AIMS)

3.1. Cloud Computing. Cloud computing is an important product of the rapid development of society and science and technology. Its main feature is that it can realize various cloud platforms such as cloud computing and provide services to users simply and quickly. In terms of technical resources, the analysis can also maximize the utilization of resources. Cloud computing technology can seamlessly connect various data on the network.

Enterprises and individuals are the main service groups of cloud computing. The cloud computing platform is implemented by using various technologies and algorithms, so the hardware cost is low. It is possible to perform the upgrade later if the technology is replaced and the code is produced. There is no need to add or replace other hardware. After using the cloud technology, the operation efficiency is also significantly improved, and the enterprise development ability and service level are also rapidly improved. In the later stage, the maintenance and upgrade operations can be completed under the network environment and will not be limited by location, time, etc. At present, the cloud service model involves 3 kinds, namely, public, private, and hybrid. Groups and individuals are the primary users of the private cloud. The general public is the primary user of the public cloud. The hybrid cloud is created by combining the public and private clouds. User groups are categorized based on their user status [12].

3.1.1. Logical Structure of Cloud Technology. NIST divides cloud technology into PaaS platform as a service, SaaS software as a service, and IaaS infrastructure and services. The SaaS is a cloud technology paradigm implemented on cloud service providers' equipment and delivered to consumers via web applications and online interfaces. Users are not required to manage or develop [13]. PaaS may give operating applications and grow users as a secondary development platform. Users can utilize the built-in applications to fulfill services without managing the underlying hardware. The IaaS model provides users with virtualization infrastructure, including network and server, so that users can run the deployed application. Organizations at home and abroad give a variety of cloud technology structure schemes based on the three levels of cloud technology and

develop a cloud technology reference framework by combining ITU-T and SO/IEC JTC 1. Figure 1 shows the logical architecture of cloud technology.

According to the above figure, the processing schemes of cloud technology structure in different countries, mainly including the PaaS platform layer, IaaS resource layer, SaaS application layer, operation support, security, business support, and integration layer provide cross-level services.

3.2. The Accounting Information and Account Information Management System

3.2.1. The Accounting Information Based on Big Data. Big data refers to a tremendous quantity of data sources with different sources, complicated and numerous kinds, higher speed of processing, and whose value may be regenerated many times, with the qualities of enormous volume, variety, fast throughput, and low population density. Big data encompasses a wide range of data kinds. Presently, accounting information is mostly collected via structured data. Simultaneously, unorganized data is critical for financial decisions. As a result, in the era of big data, businesses must gather unstructured data, raise the amount of unstructured data gathering and analyze and comprehend this data to enhance decision-making correctness.

Furthermore, Accounting Information Management System (AIMS) is a software program designed for analyzing accounting data. The AIMS is a required guarantee for successful enterprise management and judgment, which is an essential forum for corporate market analysis. The financial information system collects, saves, and evaluates financial data to analyze the enterprise's business operations and outcomes to generate financial data. Following the completion of accounting by the financial information system, the management information system starts to evaluate important data, give practical knowledge, and make smart judgments. The financial information generated by the AIMS is communicated to the management information system and analyzed to help enterprise management and judgment. A typical structure of an Accounting Information Management System (AIMS) can be represented in Figure 2.

(i) **Source of data:** These are financial transactions that are entered into the system interior as well as from exterior sources. These statistics result from financial considerations with other commercial enterprises and individuals outside the company. Transactions such as sales of products and services, inventory, buying, and collecting payments are examples. Interior financial transactions are the resources inside an organization that comprises transaction considerations. For instance, raw - materials movements, fixed cost depreciation, manufacturing stock, and labor.

(ii) **Data collection:** The initial operational step of AIMS is data collection. Before entering the procedure, data must be cleaned of significant mistakes. This step is the most crucial in many ways since there is a possibility of providing wrong information if significant mistakes are not corrected. Such occurrences might lead to improper actions and judgments by users.

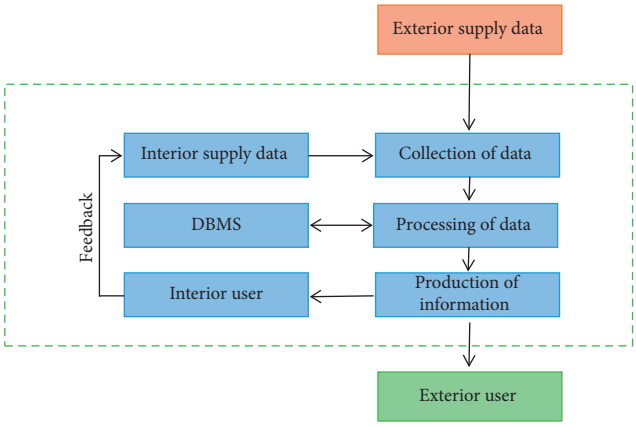

Figure 2: Typical structure of AIMS.

In data collection, there are two principles: suitability and efficacy. Only relevant data is entered into the information system. The primary responsibility of the system operator is to determine whether data are acceptable. He or she gets this by evaluating user needs. As a consequence, only relevant data will add to the information. A filter for incorrect data is created during the data collection stage. Data is acquired only once for an effective data collection step. These data can then be used by a variety of users, which may be saved and backed up later. The capability of an information system in terms of data collection, analysis, and storage is restricted. Overburdening a device while backing up data will reduce the system's efficacy.

(i) **Processing of data:** The acquired data must be processed to produce an item. Examples include mathematical algorithms used during production scheduling, analytical tools for sales forecasting, and accounting entry requirements.

(ii) **Database Management System (DBMS):** Organizational databases are physical locations for storing financial data. This storing place might be a filing cabinet or a computer disc. The three main roles of database administration are storing, retrieving, and deleting. In the storing procedure, new entries are entered and transported to an appropriate location on the database. The fetching function is used to extract an existing record from a database. After the data is processed, the saving function loads up the new data, whereas the removing function removes the old and useless data from the database.

(iii) **Production of information:** The process of organizing, structuring, and providing information to users is known as information creation. This data can be operating documentation, including a sales

order, a technical analysis, or a computer output message. A helpful piece of information has 5 elements: applicability, reality, accuracy, consistency, and summary.

3.2.2. Cloud Computing in the Era of AIMS. Conventional accounting system models cannot efficiently analyze and handle financial data in the age of big data. For this purpose, cloud computing services solutions are required. Firstly, cloud computing has extraordinary data analysis and process technology, which allows it to handle large volumes of information in a short time of time while precisely analyzing and revealing the features and underlying relationships among economic data and information. Secondly, cloud services technology can enable inter enterprise collaboration. Thorough analysis and interpretation of corporate financial data may be accomplished without raising operations and management expenses and sharing resources among multiple agencies within the enterprise. Moreover, cloud computing technology can facilitate company resource sharing and thorough evaluation and discussion of business financial information without rising operational and administration expenditures.

The virtualization of financial information and cloud services is the primary purpose of cloud computing technology. Financial data virtualization is considered one of the key technologies for implementing accounting information in the cloud. It combines both processing and analytical operations of business financial data to increase the capacity to consolidate and develop an analysis of data. Virtualization of all sorts of data saved in the cloud optimizes financial accounting information and data supplies while improving server resource efficiency. Furthermore, financial information virtualization allows users to swiftly access financial information based on various commands and discover the logical linkages hidden behind huge data.

Besides the above, the conventional AIMS is insufficiently robust wherein the processing of data is ineffective, therefore, requiring the manual collaboration of financial personnel to a great extent which considerably decreases the effectiveness of information processing. In such cases, the accounting information Management system can only offer managers past and factual analysis of data. Unfortunately, the failure to gain real-time control over the business management, financial planning process, and financial decision-making frequently causes the ideal time to deal with risks to be postponed. The AIMS, which is built on cloud computing services, promotes collaboration and data exchange among multiple company departments while also addressing the issue of financial accounting availability. The cloud computing computerized system model study's ultimate purpose is to cope with the different outputs of AIMSs and give consumers of financial data an accurate and full foundation for decision-making.

3.3. Restricted Boltzmann Machine Energy Model Based on Deep Learning Algorithm. A neural network is a typical mathematical tool used in the area of AI and machine learning. Compared with the traditional second-generation neural network, the deep learning algorithm solves the problem of low learning efficiency. It regards a multi-layer model as stacking multiple different RBM or similar unit models and then learning RBM layer by layer to realize the training of multi-layer models. Thus, the RBM model is the main content of deep learning.

A restricted Boltzmann machine (RBM) is a creative probabilistic artificial neural network good at learning a probability distribution across a collection of inputs. RBM belongs to the undirected graph probability model and is realized based on energy. Here, the joint probability distribution is defined by combining the h hidden layer vector and the x input layer vector energy function, as calculated in.

$$p(x,h) = \frac{e^{-\text{energy}(x,h)}}{z}. \tag{1}$$

The above equation, $z = \sum_{x,h} e^{-\text{erengy}(x,h)}$ represents the normalized constant or partition function, and the marginal probability distribution of observable input data x can be calculated by utilizing.

$$p(x) = \sum_h p(x,h) = \sum_h \frac{e^{-\text{energy}(x,h)}}{z}. \tag{2}$$

After introducing the free energy, the above equation can be changed as equation (3) below:

$$p(x) = \frac{e^{-\text{freeEnergy}(x)}}{z}, \tag{3}$$

$Z = \sum_x e^{-\text{freeEngy}x(x)}$. in the above equation can be calculated as per.

$$\text{freeEnergy}(x) = -\log \sum_h e^{-\text{energy}(x,h)}. \tag{4}$$

Here, B is introduced into the expression of model parameters, and the derivative of equation (4) above is calculated to obtain the following:

$$\begin{aligned} \frac{\partial \log p(x)}{\partial \theta} &= -\frac{\partial \text{freeEnergy}(x)}{\partial \theta} + \frac{1}{z}\sum_{\widehat{x}} e^{-\text{freeEnergy}(\widehat{x})} \frac{\partial \text{freeEnergy}(\widehat{x})}{\partial \theta} \\ &= -\frac{\partial \text{freeEnergy}(x)}{\partial \theta} + \sum_{\widehat{x}} p(\widehat{x}) \frac{\partial \text{freeEnergy}(\widehat{x})}{\partial \theta}. \end{aligned} \tag{5}$$

At present, the method of training $\partial \log \ p(x)/\partial\theta$ approximation is used to deal with the difficult calculation of the RBM partition function, and the definition of model parameter update rules is based on the free energy gradient of samples subject to model distribution p and samples subject to data distribution $(x - p\ (x))$.

$$E_{\widehat{p}}\left[\frac{\partial \log p(x)}{\partial \theta}\right] = -E_{\widehat{p}}\left[\frac{\partial \text{freeEnerge}(x)}{\partial \theta}\right] + E_p\left[\frac{\partial \text{freeEnerge}(\widehat{x})}{\partial \theta}\right]. \tag{6}$$

In the above equation, P represents the model probability distribution, while $\widehat{\text{P}}$ represents the empirical probability distribution of the training data set. Similarly, EP and $E\widehat{p}$ represent the expected value under the corresponding distribution probability. The first term in the formula usually

replaces the training of sample expectation value. In the second item, there are samples obtained from the P model, and the MCMC algorithm is usually used to sample the model data.

4. Design of AIMS Based on Big Data Cloud Technology

4.1. General Structure of Accounting Information Management System. This paper designs an effective and reliable accounting information management system utilizing big data cloud computing. Its essence is a cloud operation of an information management system [14]. The cloud platform design and multi-level architecture deployment are completed by merging the fundamental needs of the accounting information management system with the characteristics of different types of information software on the cloud platform, as illustrated in Figure 3 [15].

The above Figure shows the accounting information management system based on big data cloud technology. The system is composed of four layers, namely, the data layer, infrastructure layer, application layer, and management platform layer. The user logs in to the system operating system function at the smartphone client or computer PC [16]. User types mainly include enterprise management, enterprise workers, and system administrators. The system administrator has the highest authority. The infrastructure layer includes various equipment and components to provide basic support for the operation of the accounting information management system. A huge amount of data resources are stored in the data layer as the resource basis required by the accounting information management system. The management platform layer is the maintenance center of the accounting information management system, and the application layer is the service provider.

4.2. SaaS Model of Accounting Information Management System. In this paper, the persistence layer is introduced to deal with the efficiency of system data extraction, and the internal ORM mapping function is used to speed up data reading. As shown in Figure 4, the SaaS model required for this design is shown. The control layer uses the persistence layer to map data during data reading and then reads data information after passing through the data layer.

The main part of the scheme is the persistence layer ORM, which is further processed and processed, based on the Dao architecture, and the database layer and business logic layer are selected to build an interaction center. Historical data is sent to the accounting information management system for analysis via the persistence layer, and the processing procedure is optimized. There is no need to transmit or duplicate data for processing to enhance the overall effectiveness of data interaction [17]. The persistence layer's core modules use the mapping concept to extract and retrieve database information. The data reading and writing process are different from the data reading and writing function of SQL statements. It can quickly enhance the data reading speed and simplify the data extraction process, to greatly enhance all processes of the scheme.

4.3. Distributed Storage Based on Cloud Platform. Based on the cloud platform of the established accounting information management system, a large amount of financial data and materials of the enterprise are stored in a distributed storage model [18]. Generally, the previous accounting information office system mainly focused on the centralized storage of financial data in the server, which could not achieve the purpose of storing a large amount of data. It could only extract some local data and provide basic business operations and services to local customers, resulting in limitations and regional restrictions in the application of the system and the satisfaction of company users when using the system. The distributed storage strategy used in this study may circumvent regional limits, find the user region, and preserve financial data from each branch firm based on various regions. As a result, the system's data storage efficiency has been greatly increased, as have the system's application efficiency and security. As shown in Figure 5, the distributed storage scheme is based on a cloud platform.

The above figure shows the distributed storage mode based on a cloud platform. The system can save the accounting data of branches and departments of large group companies in different regions of the country in the accounting information system [19]. Figures 1, 3, and 4 depict accounting systems from three distinct branches that are communicated to the cloud database via the established accounting information cloud platform. The data on this platform allows the finance departments of various branches to exchange their data resources. As a result, corporate managers and employees may log in to the system and query the financial data of various branches. While departments of the group firm master its operation condition, properly comprehend the business's overall capital flow, prevent enterprise business limits, and shorten the system operation cycle. At the same time, the accounting information systems of branches set up in different regions will save the corresponding accounting data in the local resource database. Where it utilizes the cloud platform to consistently manage and analyze the financial data of each area to maximize business resources and achieve resource and financial information sharing [20].

5. System Testing and Simulation

This study proposes an accounting information management system based on big data cloud technology for managing business finances based on accounting data informatization [21]. In this paper, the system cluster test is carried out experimentally. The test contents include job timeliness, data locality, load balance, and so on. The job forms adopted in the experiment are modified, inquiry and TeraSort. The inquiry job is used to query the reimbursement time or vouchers. There are many disk UO operations required in the operation phase, which can accurately detect

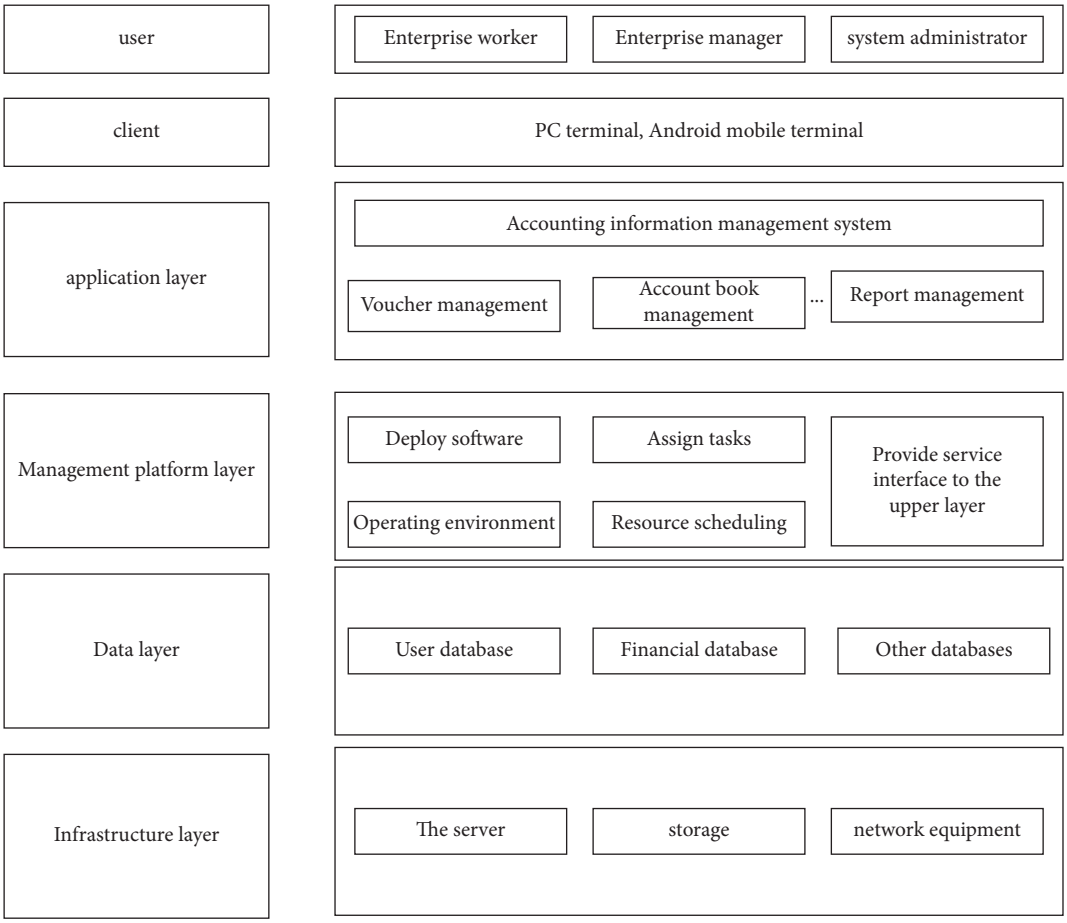

Figure 3: System cloud platform architecture.

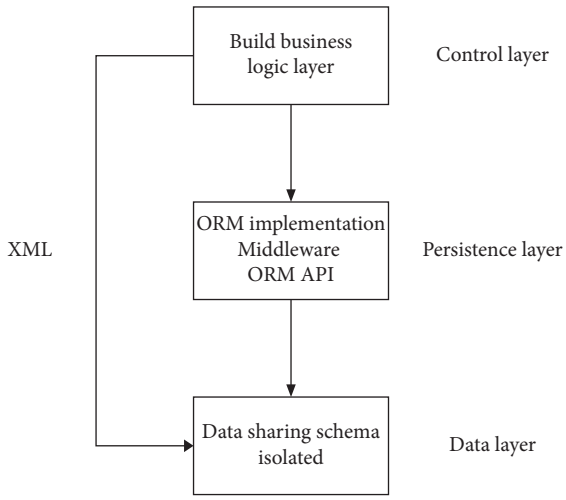

Figure 4: SaaS model of accounting information management system.

the platform task throughput and load status. TeraSort is the main tool for testing the cloud platform. It can input financial information into the accounting information management system without processing the output data. The modified job is used to represent mechanism vouchers or manual vouchers. After changing the job information, the new data is captured in the HBase database, and the prior information is erased. Under the premise of the same input data for the above three different job forms, in the output data volume, modify is higher than TeraSort, and TeraSort is higher than inquiry. Select the corresponding task scheduling based on the fair scheduling algorithm.

5.1. Job Response Time. When assessing the job response time in this article, it is assumed that each task has 10 decreases and 100 maps. All machines run tasks at the same time. At the same time, there are certain differences in the amount of data during task execution, which can fully reflect the fairness of scheduling. The job response time of the system is listed in Table 1.

According to the data in the preceding table, assuming that the input tasks are entirely consistent, the response relationship of various tasks is that modify surpasses teraport and TeraSort exceeds inquiry. Because the tasks of teraport and reducer are relatively simple, the efficiency of running jobs is faster than that of modifying jobs. The number of reduce and inquiry tasks is small, so the required cycle is short. An in-depth data study reveals that when the amount of data is little, hence the effect of utilizing the Hadoop platform in the system is less than that of not using

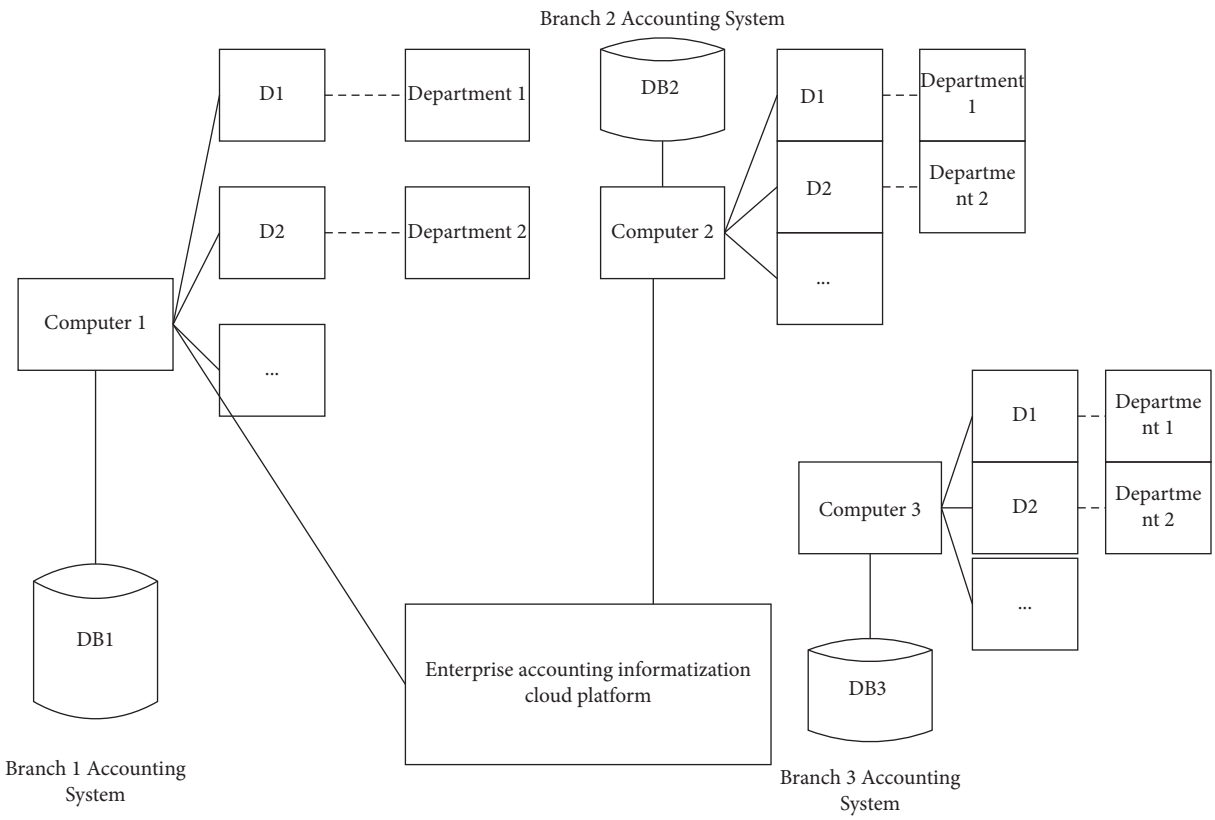

Figure 5: Distributed storage scheme based on a cloud platform.

the Hadoop platform. The effect of this system platform is remarkable after continuously increasing the amount of data. After the amount of input data increased to 2560m, the modification task decreased significantly, from 920 to 876 with an increase of 4.78%. The teraport mission was decreased from 672 s to 654 s, a 2.68% increase, fulfilling the target. The query task has grown by 6.8%, from 247 s to 265 s.

The number of reduced task slots in the Hadoop cluster directly affects the balanced load results. Here, the input job is set to 1280 M, and there are 8 map task volumes. Different task slot numbers can be obtained, which affect the job response time of the accounting information system. In this paper, the above three different task modes are used, and there are two scheduling modes. The data obtained are shown in Table 2, in which OBDN belongs to the improved scheduling algorithm.

To enable tasks to select jobs evenly and randomly, the jobs belong to teraport, so there is a large amount of output data. The advantage of this method is that it can better detect the actual running status of all nodes. The 1280 M job input data, 8 map tasks, and 8 reduced tasks set here are shown in Figure 6.

According to the response time results of the reduced task shown in Figure 5 above, adding load balancing can keep the processing cycles of all reduced slot tasks in a stable state. During the scheduling decision-making period of fair and OBDN, there are differences in the standard deviation and mean value of the operation cycle. The mean value of fair is 218, and the standard deviation is 30.79. The standard deviation and mean value of fair scheduling decisions are 13.02 and 214 respectively. Therefore, it is concluded that the average operation time of the reduced task slot cannot be increased during teraport operation, while the processing cycles of all tasks are relatively balanced. The operation cycle of reduction is balanced, and its movement speed is relatively uniform, which can maximize the use of reduction.

Table 1: Operating system response time on platforms with different data volumes.

Whether to use Hadoop data volume	320 M	640 M	1280 M	2560 M
N-Hadoop modify	11	224	453	920
Hadoop modify	139	236	441	882
N-Hadoop TeraSort	79	163	331	672
Hadoop TeraSort	86	171	330	655
N-Hadoop inquiry	33	66	132	265
Hadoop inquiry	31	61	120	247

Table 2: Job response time of different degree algorithms.

Scheduling algorithm Number of reduced slots	2	4	8	16
Modify OBDN	762	593	450	393
Modify fair	801	612	414	381
TeraSort OBDN	630	448	327	267
TeraSort fair	654	469	292	251
Inquiry fair	419	275	127	78
Inquiry OBDN	440	288	141	91

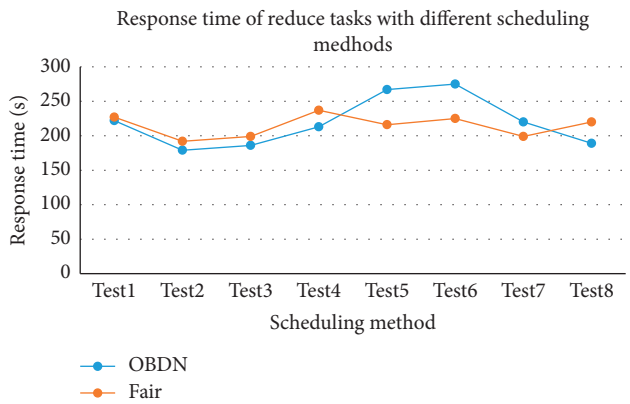

Figure 6: Response time of reduced tasks with different scheduling methods.

5.2. Analysis of System Task Locality and Acceleration Rate

5.2.1. Task Locality Analysis. In this paper, when detecting the local characteristics of cluster data, the size of the local data row directly affects the speed of the accounting information management system. In this paper, teraport, modify and inquiry run together, and each job is set to have 320m of input data and 8 reduced tasks. Three different types of jobs should be submitted at the same time by a shell script. After completion, continue to run three times and then count the number of all local tasks. Equation (7) is used for calculating the local rate of tasks.

$$\text{DataLocalityRate} = \frac{1}{n}. \tag{7}$$

After the fair scheduling policy has been run three times, the number of local tasks is 20, 28, 40, and 49, and the number of local tasks of the OBDN scheduling policy is 19, 31, 46, and 52. The data obtained is shown in Figure 7.

According to the above Figure, after the number of map tasks was adjusted from 4 to 10, there was no significant change in the OBDN scheduling strategy as a whole. The local rate is lower than the OBDN when the fair scheduling policy has four task slots. After the number of reduced tasks, slots continue to increase then the local rate increases slightly. However, when the number of reduced task slots increases to 10 then the local rate decreases.

5.2.2. Acceleration Rate Analysis. During this experiment, Wordcount and TeraSort were used as two workloads to analyze the impact of task size on the system acceleration rate. Set 1 g of job input here, including 6 map tasks and 12 reduce tasks. The relationship between execution time and CPU utilization is shown in Figure 8.

The task execution cycle is lengthened once the CPU uses increases, as can be seen by evaluating the data in the aforementioned Figure. Wordcount and TeraSort workloads are sensitive to CPU usage in different ways, and Hadoop accelerates more quickly.

Figure 9 explains the comparison of the Job response time of various degree algorithms. By analyzing this figure, it

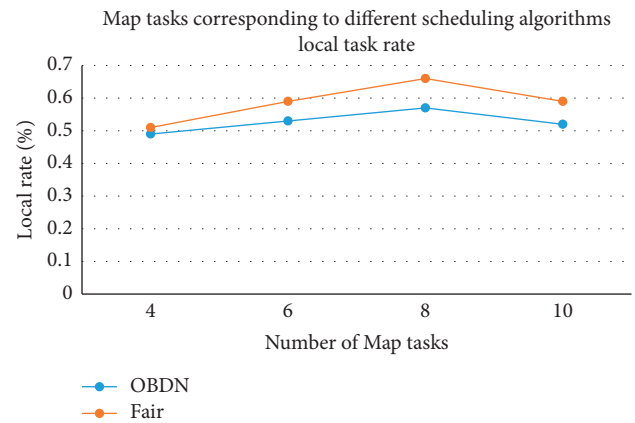

Figure 7: Map tasks corresponding to different scheduling algorithms' local task rates.

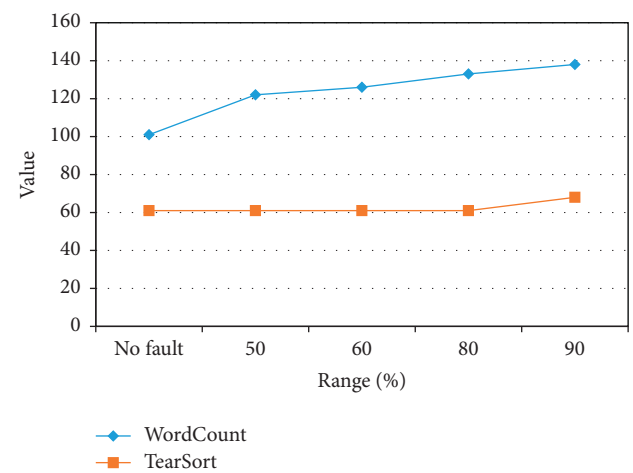

Figure 8: Relationship between execution time and CPU utilization.

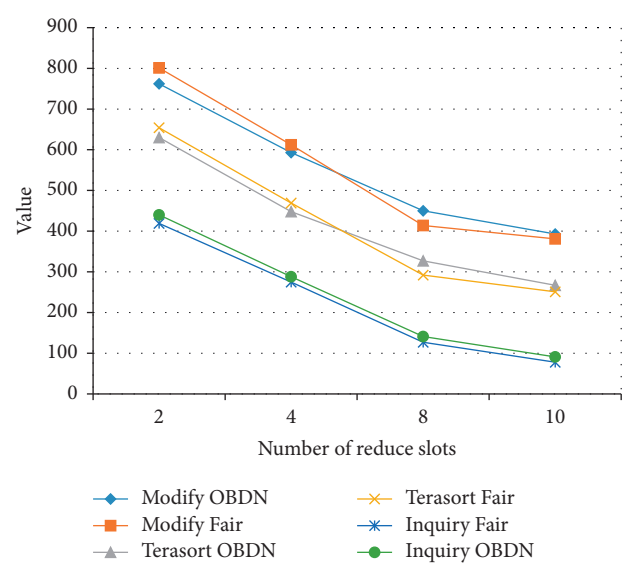

Figure 9: Comparison of the job response time of various degree algorithms.

can be seen that the OBDN scheduling method is better than fair after reducing the number of reduced slots on the premise that the job scheduling strategy is completely consistent. After continuously increasing the number of slots, the feature of the fair can be better reflected. When reduce is the number of 8 task slots, the modified task time will be reduced to a certain extent, from 450 s to 414 s, and teraport from 327 s to 292 s.

6. Conclusions

Nowadays, the quick expansion of information technology and network knowledge has promoted the popularization of automation, intelligence, informatization, and other high-tech technologies in people's lives. To compete in the market, businesses must increase their exterior operations strategies and establish internal management informatization. Accounting informatization management has become the basis of enterprise financial organization which can effectively enhance the informatization ability of enterprise financial management, reduce costs, achieve efficient office work, and improve the accuracy of financial data. Therefore, this work uses big data cloud technology to design and develop the accounting information management system and uses the system to complete the enterprise financial data management, to better coordinate the resources and personnel of the financial department. The distributed data storage of the cloud platform is adopted, and the system cluster performance is evaluated to determine the system application impact, by developing the cloud platform architecture and SaaS model of the accounting information management system based on cloud technology. This article examines the system's application effect from three perspectives: work time, data local row, and load balance. As per the results, the system has high efficiency, acceleration rate, and task execution rate.

Data Availability

The data are included in the article.

Conflicts of Interest

The authors do not have any conflicts of interest in the publication of this paper.

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Research Article

Designing an Intelligent Teaching System of Chinese as a Foreign Language under the Internet Background

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To overcome the limitations of the traditional teaching system and improve learners' language learning efficiency by incorporating personalized allocation of learning resources and learning evaluation into the Chinese as a foreign language teaching system (CFLTS). This paper aims to deeply study the overall design of the intelligent teaching system (ITS) for CFLTS. Firstly, this paper develops an ITS for CFLTS. It focuses on the intelligence teaching system's structural planning and structural design. The system functional structure and the specific characteristics and recommendations module constitute a two-way teaching quality evaluation module. The elite teaching optimization algorithm based on the feedback mechanism is adopted. The students are divided into excellent and poor students after the feedback mechanism is added to split the student stage. Next, they dynamically adjust the scale of excellent and poor students, conduct feedback communication between poor students and teachers, and strengthen the convergence ability. Finally, self-learning for good students is arranged by performing an excellent local search and including the feedback stage to broaden the range of learning methods and improve the ability to find global teaching resources. The completion of all these steps ensures that the design of an ITS for CFLTS is now complete. According to the experimental results, the ITS proposed in this work has a higher level of overall stability, effectively improves students' learning efficiency and teaching quality, and can better meet the needs of Chinese language learners.

1. Introduction

The Internet must assess established communication channels and instructional techniques from the perception of teaching training. Change roles and concepts, arrange unstructured oral Chinese teaching resources, and naturally merge contemporary knowledge with traditional language teaching techniques [1]. To regulate the learning process, teachers must be able to build the learning process utilizing network Internet resources to have each student's learning material through the network. Intelligent computer-assisted educational reforms are the result of a collaboration between pedagogy, psychology, computer science, behavioral science, and artificial intelligence (AI) [2]. The study's ultimate purpose is to empower the computer system to do suitable educational and instructional activities, that is, to add intelligence to the software system so that it can incompletely change teachers and deliver the best possible instruction. [3]. The accessibility of modern digital education in this country surely increases the number of learning environments available for CLT. The public appears to be fetching even further involved in Internet education, which has resulted in the development of more integration and interaction technologies. Due to the increasingly complex characteristics and spatially and temporally separated nature of the Internet backbone education atmosphere, management and teachers are finding it difficult to acquire effective learning data from online students [4].

As a result, there is a one-sided search for quantity and size in the pushing mode of educational materials and simple replication of textbook contents of resources. Implementing a system to collect accurate education information and updates and provide individualized learning services for such a large number of online learners has become a critical challenge [5]. In the context of the Internet, with the gradual popularization of computers and different types of mobile intelligent terminals, the intelligent teaching system with learners as the main body is gradually loved by learners,

which has an impact and changed foreign language teaching methods to a certain extent. Because of the development of economic growth and the significant growth of international commerce, the number of individuals studying Chinese as a second language is steadily increasing [6]. Due to a serious lack of CFLT, improving the teaching quality and learning efficiency of CFL through automation has emerged as the most essential problem to be addressed. The rapid development of information technologies in the twenty-first century provides an excellent opportunity for the creation and implementation of an intelligent teaching system for CFL.

Domestic research and development of intelligent teaching systems for Chinese as a foreign language have evolved in recent years, with some results, as artificial intelligence technology has matured. Li and Wang evaluated the rapid expansion of artificial intelligence and its widespread use in many areas of society, summarizing the practical demands of Chinese as a foreign language intelligent conversation and conversation system. The study's findings have been utilized to investigate the system structure and notion of Chinese as a foreign language both at home and abroad. The intelligent learning system is based on chat robots and takes situational learning theory, constructive learning theory, and artificial intelligence natural language processing technology as guidance. Make sentence word segmentation and calculation based on a vector space model to complete the similarity matching of Chinese sentence semantics and use the TF-IDF algorithm to match keywords. The target is to realize the automatic questions and answers by establishing a chat robot based on artifical templates and rules; then, the datailed unique functions and specific effects of the application practice will be introduced. The implementation of the intelligent system for teaching Chinese as a foreign language is now in progress. Due to the complexity of the process, the teaching quality has not been effectively improved [7]. The rapid development of artificial intelligence technologies in recent years has been proposed by Hua and He. Natural language understanding and processing technology have become the primary focus of the integration of artificial intelligence and linguistics. A highly interactive intelligent teaching system is designed based on Internet NLU and NLP technology, as well as the characteristics of CFL. Using pre-existing intelligent teaching equipment, the intelligent teaching system creates an intelligent teaching environment, writes teaching cases, and establishes a multidirectional teaching assessment system. By applying the designed teaching system scientifically to teaching Chinese as a foreign language, promoting fundamental changes in teaching forms, and providing effective assistance for the establishment of learners' learning environments and personalized learning, the establishment of a new intelligent teaching system has altered the relationship between teachers and students, but this method does not improve learning efficiency [8]. This study aims at the problem of the slow response time of traditional teaching systems and designs an intelligent teaching system for a foreign language. Under big data, the hardware part of the system uses a CCD device to design the sensor, which is connected to the laser feedback device and uses a dual-core processor. The device uses multitouch technology to design the high-definition touch interactive mirror device and connects the mirror device to the camera to form a touch platform. Big data technology is used to deal with the specific situation of students' knowledge; a Bayesian formula is used to summarize the teaching data; and Java programming is used as an input. So the teaching data is needed to comprehensive the software design of an intelligent teaching system. As compared to previous intelligent teaching systems, the experimental results show that the system reaction time in practical operation is substantially improved, but students' overall learning efficiency is inadequate [9].

The perspective of learning subjects, the intelligent CFLTS, and the Internet can support students to overcome barriers. When learners encounter problems while learning Chinese, the ITS provides timely and modified guidance based on learning time, learning space, teachers, and curriculum. The ability of educators to use and develop intelligent teaching systems and also teachers' professional quality is highly dependent on new technology. The existing intelligent teaching method for Chinese as a foreign language, according to the results, has a limited applicability level. The original ideas, particularly in the area of intelligent design, must be improved to improved meeting the requirements of modified and autonomous learning.

The following are the paper innovations:

(i) Firstly, the elite teaching optimization algorithm based on the feedback mechanism is used to develop an intelligent teaching system for Chinese as a foreign language

(ii) Secondly, the student stage is carried out, the feedback mechanism is added to divide the students into excellent students and poor students, and the scale of excellent students and poor students is dynamically adjusted

(iii) Thirdly, the feedback stage is added to the development of the diversity of education methods and improves the ability to search for global teaching resources

(iv) Finally, the overall stability of the intelligent teaching system of Chinese as a foreign language designed in this study is highly efficient as compared to the traditional teaching system, and it can effectively increase students' learning efficiency and teaching quality

The rest of this paper is organized as follows: Section 2 shows related work; Section 3 shows the design of an intelligent teaching system for Chinese as a foreign language; Section 4 shows the optimization algorithm for elite teaching CFLT based on the feedback mechanism; Section 5 shows the analysis and experimental results; and finally, in Section 6, the research work is concluded.

2. Related Work

The literature aims to assemble a huge number of resources on the Internet, and the information resources are easily categorized together, resulting in the phenomenon of data information islands, which leads to a poor sharing effect of teaching and waste of teaching resources. Therefore, Ma JC introduced a multinetwork ITS for CFL and shared teaching resource data using the logic control center. The logic control center's

resource sharing module, for example, uses a structured peer-to-peer network. The query, positioning, and sharing of intelligent teaching resources for CFL are completed through mutual communication between the node and the execution node. After the classroom subcontrol switches the signal, the system's control module sends it to the centralized teaching control. As a result, data and communication management must be realized. The teaching system employs the multinode network algorithm to select the node with the smallest variance value as the outlet to ensure the remaining load capacity of the shared network node. The system is strong and effectively transmits teaching resources for intelligent teaching. The intelligent teaching system's network swallowing volume is substantially higher than the comparison system's, yet the system does not influence the quality of teaching CFL, according to the experiment [10]. According to the authors of this study, the current network teaching platform includes a wide range of learning resources, and each platform focuses on developing students' skills in specific areas rather than creating an overall capacity for writing, listening, reading, and speaking [11]. In the author's design, modern information technology and traditional language training methodologies are seamlessly integrated. To regulate the learning process, teachers should be able to create the learning process using network resources and obtain each learning and teaching relevant information [12]. The authors of the study created a student model that is in charge of representing students' knowledge level, learning style, cognitive capacity, education olden times modification, learning motivation, and further data systematically [13]. These problems in the present Chinese language network teaching platform, proposed in this study, must be easily resolved, and it is vital to establish a complete, interactive, personalized, and feedback-capable CLT platform [14]. The authors of this study present the primary characteristics of a network teaching platform to display students' characteristics and attitudes and to provide a framework for the development of intelligent teaching objectives, educational resources, and teaching methods [15]. According to the literature, teaching practices must encompass cognitive ability, motor skills, and emotions, with cognitive ability objectives separated into six categories based on the difficulty of intellectual activity [16]. The author of this paper suggested a design for an intelligent network teaching system. This author's purpose is to develop a Chinese language teaching system approach based on DL, based on previous research and the current condition of the Chinese language network teaching system. It also categorizes students' learning styles and offers alternative teaching tactics and materials based on their preferences. The approach may create a customized environment for learning depending on the characteristics of learners in real time, allowing for truly individualized instruction [17].

3. Development of an Intelligent Chinese as a Foreign Language Teaching System

3.1. Intelligent Teaching System Structure Designed for Chinese as a Foreign Language. Figure 1 shows the ITS structure planning for Chinese as a foreign language:

(1) The user interface for the system structure is simple and clear, generous, and attractive. It supports the intelligent navigation feature and can operate and retrieve in more ways.

(2) Create a social framework for teaching methods.

(3) Improve the intelligence of the intelligent teaching system through natural language processing technology and hypermedia technology [18, 19].

3.2. The Functional Structure Design of an Intelligent Teaching System (ITS). Figure 2 shows the functional structure design of the ITS. The intelligent teaching system for Chinese as a foreign language mainly adopts the structure of the multilayer system, including four layers, specifically the client and content layer, and also the service layer and data layer.

3.2.1. Client. It specifically includes administrators, teachers, and students, which are accessed by a browser, while the server is collected of a content layer, data layer, and service layer [20, 21].

3.2.2. Content Layer. The specific function is similar to the navigation home page. It is provided to the client based on the user's personalized interface and the intelligent teaching system's teaching content. Other modules in the intelligent teaching system need to use the navigation home page to enter the navigation page of the system. When entering the navigation page, they need to pass the identity authentication; otherwise, they cannot enter the teaching system page.

3.2.3. Service Layer. The application service layer and the public service layer are two types of service layers. Teaching functions are provided by the application service layer, which is divided into communication and learning modules. The TCFL system relies heavily on the learning module. Users communicate in a variety of ways, one of which is through communication. The application service layer is the teaching function layer in the ITS system of CFL [22, 23].

3.2.4. Data Layer. The specific function is to save the received teaching resource data, including four modules: archives of learning CFL, learning planning and problem-solving database, and teaching resource database. The specific function of the archive's module of learning CFL is to record the knowledge level mastered after learning in the ITS, and it is also the main source of screening personalized information.

In the ITS of CFL, multiple modules such as the client and content layer, service layer, and data layer cooperate to complete intelligent teaching. Pronunciation and vocabulary, grammar, and Chinese characters are all taught as language elements in the ITS of CFL. Table 1 shows the analysis of specific features.

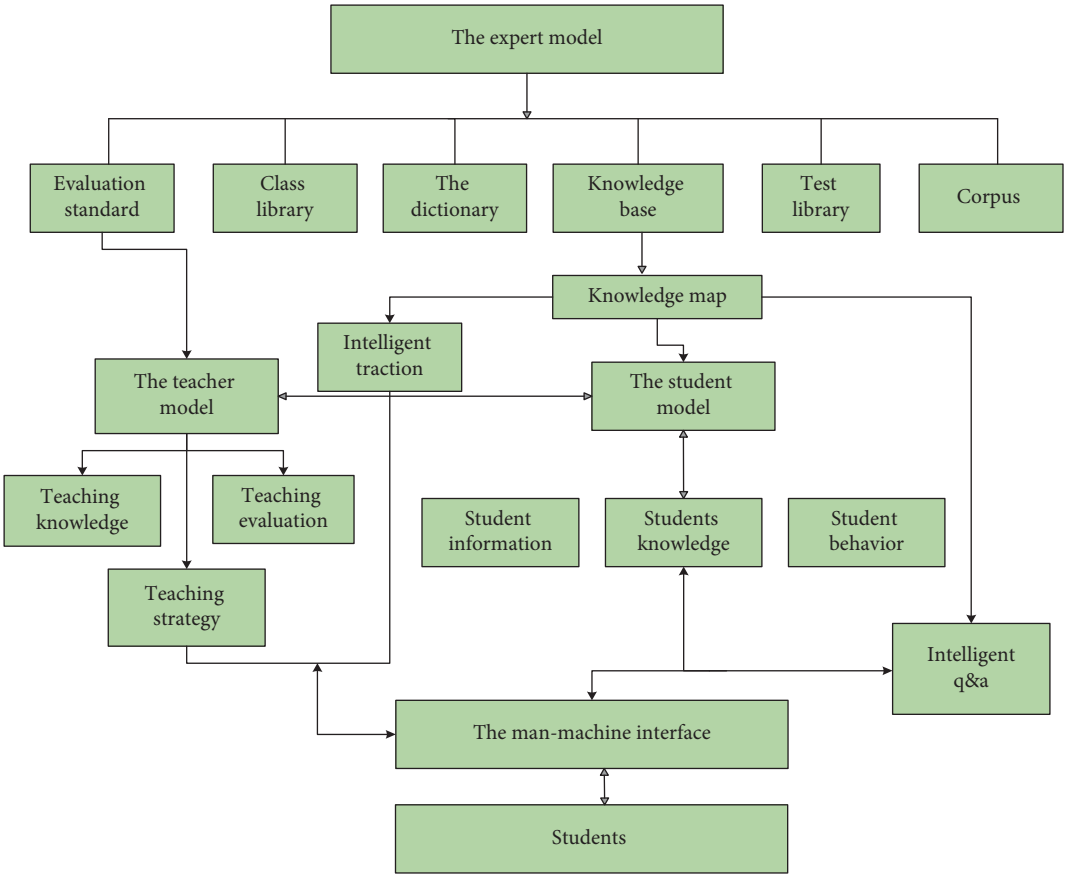

Figure 1: Basic diagram of TCSL lexical structure planning.

3.3. Recommendation Module in the ITS. In an ITS, the recommendation module has three parts: it generates user characteristics, matches the information, and generates recommendations. Collect the user's use demand, interest demand, and other data and calculate the data for teaching CFL using the appropriate technology. The results are shown as in Figure 3.

In Figure 3, the recommendation module in the ITS of CFL is divided into three steps:

(1) Convert the user's behavioral characteristics into user data and then generate feature vectors

(2) According to the different categories of user data and the selected corresponding structure, they choose the data similar to the user's feature vector and then generate the data table to complete the data recommendation of teaching resources

(3) Make statistics and arrange the recommended results analyzed in step (2) to complete the recommendation [24, 25]

3.4. Two-Way Evaluation Module for Teaching CFL. As shown in Figure 4, the two-way evaluation module has good usability and interactivity and can perform functions such as intelligent attendance, classroom discipline monitoring, and feedback on teaching results. Figure 4 shows a teacher terminal, an educational terminal, a student terminal, and a classroom terminal connected to a cloud server via mobile network communication. Classroom terminal data collection is an image processing technology that uses the camera for frame processing. The system uses a detection model of an image target and a face detection model to identify and analyze the collected data, allowing timely updates of stored data and feedback data. The terminal of a classroom is mainly set up in the classroom, which consists of four units: the processing unit, the data collection unit, the terminal management unit, and the network communication unit. The client consists of a classroom terminal and a teaching terminal and consists of three functions: sending, receiving, and displaying [26, 27].

4. Optimization Algorithm for Elite Teaching of CFL Based on the Feedback Mechanism

The elite teaching optimization algorithm of the feedback mechanism takes the population as the whole class. The optimal individual in the population is the teacher. So, to realize the optimization evolution, the teacher improves the average score of the class by carrying out teaching activities. The ultimate purpose is to improve their academic performances and promote the absorption of CFL knowledge [28, 29].

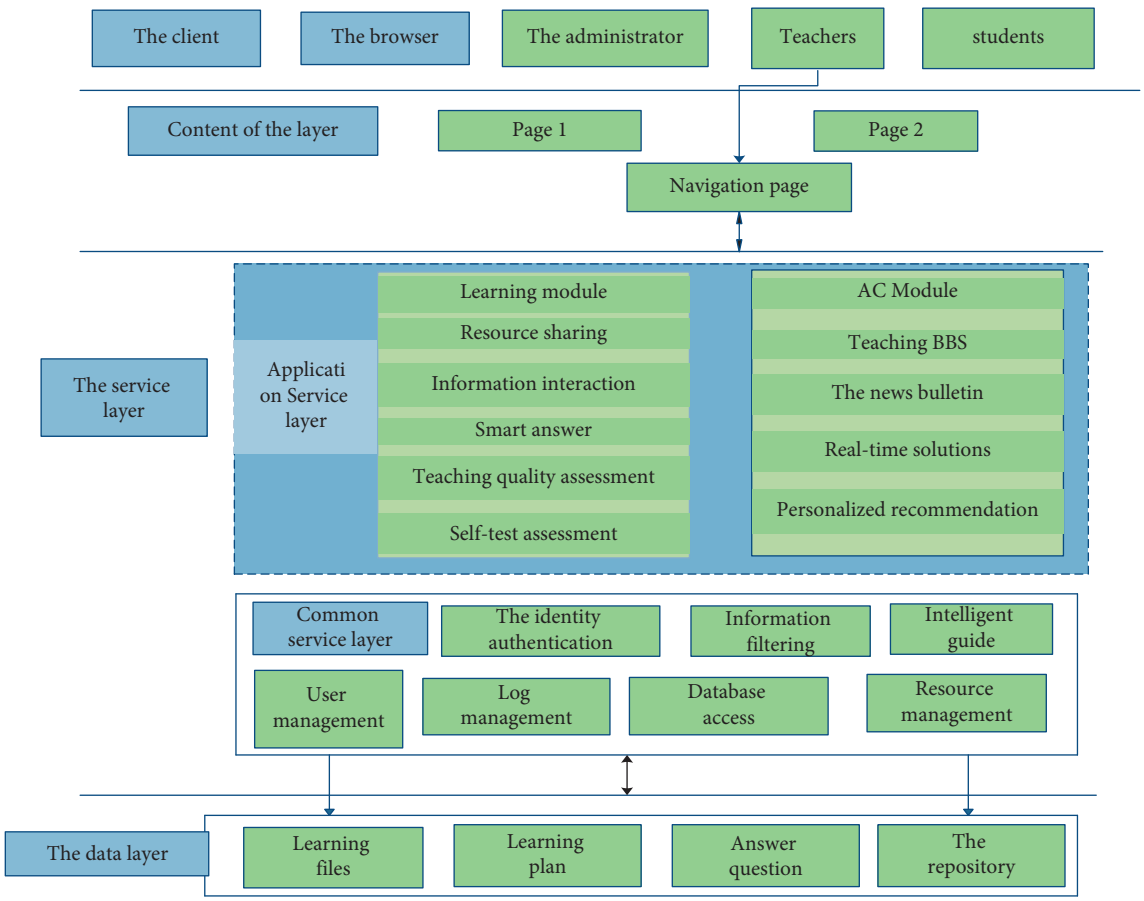

Figure 2: System functional structure design framework.

Table 1: Analysis of characteristics of ITS of CFL.

Category	The name of the system	The main advantages	Main drawback
Voice	Pinyin Trainer Android/IOS	Consonant, vowel, combination, and tone pronunciation	Teaching is not combined with Chinese characters
	Pinyin phonetic iOS	Initial, final, combined, and tetra tonic sounds	Teaching is not combined with Chinese characters
Vocabulary	Pleco Chinese Dictionary IOS	Rich entries and examples Entries updated in time	Not integrated with vocabulary teaching strategies
	Train Chinese Android/IOS	Vocabulary is classified by situation and HSK level	Vocabulary not accompanied by pictures, audio, and video
Chinese characters	Chinese writer Android/IOS	Chinese characters are classified according to HSK level	The structural meaning of Chinese characters is not explained with pictures, audio, and video

4.1. Teacher Stage. The teacher stage simulates the process of teaching CFL as the best individual in the population is the teacher. The ITS of CFL teachers helps students improve their academic performance to improve the comprehensive level of the class. In the number i of any iteration, the amount of public in the CFL class is n. The average value of academic performance is M_i, and the teaching CFL teacher is T_i. The Chinese foreign language teacher T tries to make the average value of academic performance M closer to his own level. Therefore, the new average value of academic performance M_{new} is close to T_i. The difference between the current average value of academic performance in a foreign language and the new average value is expressed by the following formula:

$$\text{Difference\_Mean}_i = r_i\left(M_{\text{new}} - T_f M_i\right), \tag{1}$$

where r_i represents the random number between 0 and 1 and T_f represents the teaching factor. Teaching the CFL system plays a decisive role in the change degree of the average value of academic performance. T_f and publicity (2) are determined as follows:

$$T_f = \text{round}\left[1 + \text{rand}\left(0, 1\right)\right]. \tag{2}$$

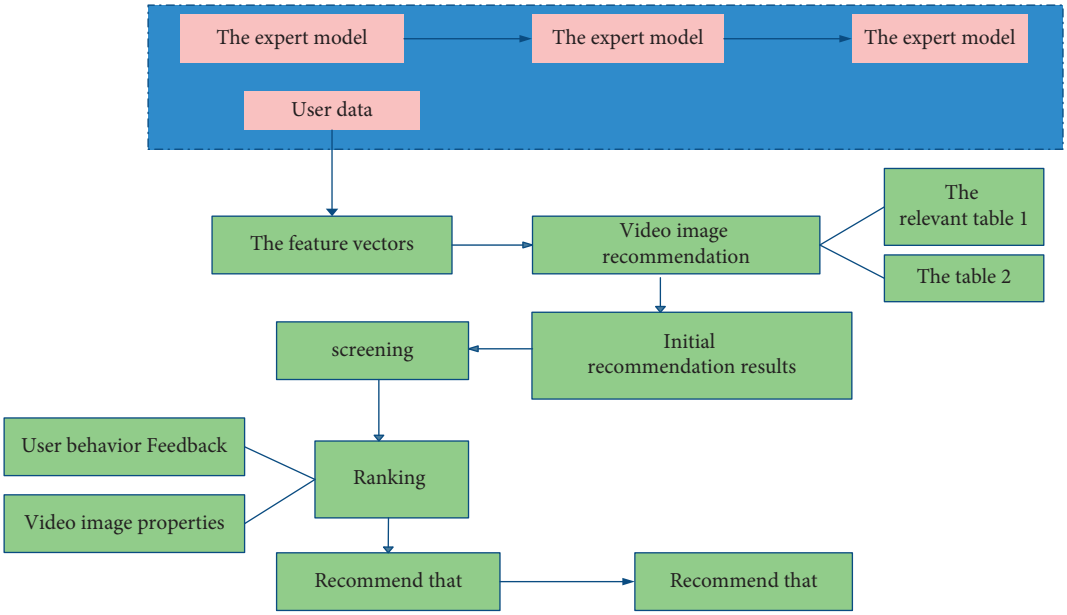

Figure 3: Big data personalized recommendation module.

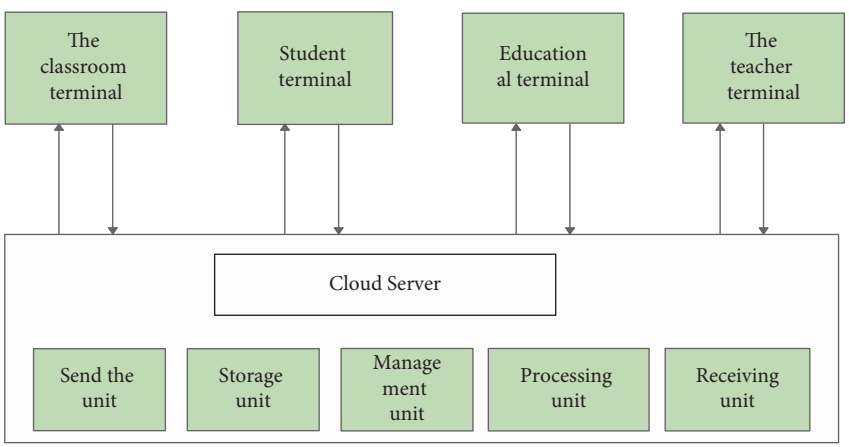

Figure 4: Bidirectional assessment module of intelligent teaching quality.

The teacher phase updates the present solution according to the following formula:

$$x_{\text{new},i} = x_{\text{old},i} + \text{Difference\_Mean}_i. \quad (3)$$

In equation (3), if x_{new} is better than x_{old}, x_{newis} retained; otherwise, x_{new} is discarded.

4.2. Student Stage. Generally speaking, Chinese as foreign language students need to adopt two ways to improve their academic performance. They are learning CFL through teachers' teaching and acquiring knowledge of Chinese as a foreign language through mutual communication among students. The student phase is a method in which students learn from one another to enhance their knowledge level [30, 31]. If the teaching problem to be solved is the minimum value problem, let x be the independent variable and $f(x)$ represent the objective function of the teaching optimization problem. After the teacher stage, randomly select two different students x_i and x_h and use the comparison of the corresponding function value of the students. If $f(x_i) \leq f(x_h)$, it means that the student x_i is better than x_h. Therefore, x_{new} gradually approaches x_i; otherwise, the students x_h is better than the student x_i, and x_{new} gradually approaches x_h. The update formula is represented by the following formulas:

$$f(x_i) \prec f(x_h), x_{\text{new},i} = x_{\text{old},i} + \text{rand}_i(x_i - x_h), \quad (4)$$

$$f(x_h) \prec f(x_i), x_{\text{new},i} = x_{\text{old},i} + \text{rand}_i(x_h - x_i). \quad (5)$$

Compare the efficiency value of the new solution after the student phase x_{new} with that of the current solution x_{old}. If $f(x_{\text{new}}) \prec f(x_{\text{old}})$, x_{new} can be accepted; otherwise, x_{new} will be abandoned.

An elite teaching algorithm of TCFL based on a feedback mechanism is proposed. The feedback process is to calculate

the students' scores after the student stage. The fitness value is $f(x_i)$ compared with the average grade f_{Mean} of the class; the class students are divided into excellent students and poor students [32, 33]. Students with poor academic performance must actively engage in feedback and communication with teachers, as well as strengthen their weak knowledge areas. However, to improve the learning levels of students with excellent academic performance, the knowledge of CFL obtained from teachers is limited. The way to obtain knowledge depends on independent education to improve their learning performance in this procedure.

Add a coefficient to the usual performance of learning CFL λ. There is a correlation between the coefficient and the number of iterations, which makes the top students learning CFL increase dynamically with the increase of the number of iterations. The coefficient position is represented by the following formula:

$$\lambda = \frac{i_{\max}}{i_{\max}}, \tag{6}$$

where i represents the number of present iterations and $i_{\max}$ represents the number of maximum iterations. λf_{Mean} is the criterion to distinguish excellent students from poor students in learning Chinese as a foreign language.

It can be realized from the above contents that the feedback mechanism is described in detail as follows: after the student phase, the suitability value $f(x_i)$ of the student is calculated and compared with the judgment standard λf_{Mean}. If $f(x_i) > \lambda f_{\text{Mean}}$, it is a poor student. It communicates with the teacher and gives feedback, which is shown by formula (7). On the contrary, it is a top student. It carries out self-learning feedback and adds small probability variation events, which are expressed by formulas (8) and (9).

$$f(x_i) > \lambda f_{\text{Mean}}, x_{\text{new},i} = x_{\text{old},i} + \text{rand}_i (x_{\text{teacher}} - x_i), \tag{7}$$

$$f(x_i) < \lambda f_{\text{Mean}}, \quad \text{rand} > M_r,\ x_{\text{new},i} = x_{\text{old},i} + \text{rand} \cdot \left(\frac{i}{i_{\max}^{U^L}}\right), \tag{8}$$

$$f(x_i) < \lambda f_{\text{Mean}}, \quad \text{rand} < M_r,\ x_{\text{new},i} = x^L + \text{rand} \cdot \left(x^U - x^L\right), \tag{9}$$

where M_r represents the random variation probability, and the value in this paper is 0.05; x^U represents the solutions space's upper bound; and x^L represents the lower bound of the solution space.

After adding the feedback phase, associate the suitability value between the novel solution x_{new} and the present solution x_{old}. If x_{new} is better than x_{old}, x_{new} is accepted. After joining the Internet, the student's ability to learn Chinese as a foreign language is improved. The ability of students to learn CFL is improved by combining the diversity of algorithm design with the background of CFL.

Table 2: Environment for experimentation.

The test environment	Data
Server version	Tomcat 6.0
Background database	MS SQL Server 2000
Client running environment	Windows 2003
CPU	2 × 2.6 GHz
System memory	2G
Testing tools	Load Runner 7.8

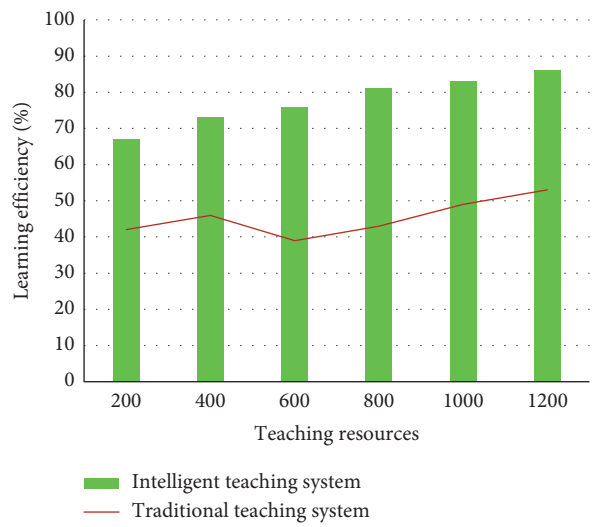

Figure 5: Comparison of the improvement of learning efficiency of different systems.

Table 3: Comparison of time consumed by 500 iterations of the test function.

Different teaching methods	Time (s)
Feedback mechanisms for elite teaching	7.812
The traditional teaching	9.135

5. Analysis and Experimental Result

Experiments are being carried out to test the performance of the intelligent CFLTS in an Internet environment. The environment for experimentation is depicted in Table 2.

Figure 5 shows the comparison of learning efficiency between the intelligent teaching system of CFL and traditional teaching.

Figure 5 shows that the learning efficiency of the ITS of CFL suggest in this work is comparatively high in the early stages of teaching resource learning. Learning efficiency improves over time as teaching resources increase, whereas in the early stages of the experiment, improvements in the learning efficiency of the traditional teaching system are not readily apparent. When teaching resources are increased to 600, they decrease and then increase, indicating that overall learning efficiency is low and that there are still some fluctuations. This shows that the ITS for CFL used in this paper can significantly improve the efficiency of students' learning after 500 iterations. Table 3 compares the elite teaching optimization algorithm proposed to the traditional teaching optimization algorithm in terms of time.

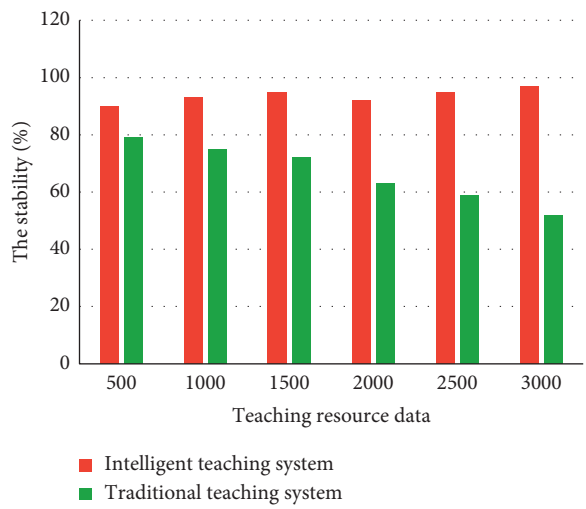

Figure 6: Comparison of stability of different teaching systems.

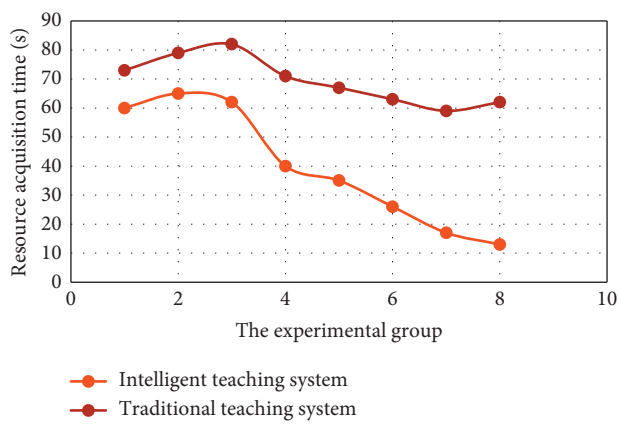

Figure 7: Time comparison of acquisition of teaching resource data by different systems.

Table 3 shows that the elite teaching optimization technique proposed in this paper, which is based on a feedback mechanism, can quickly converge near the value's optimal solution. The 500-iteration time is faster than the traditional teaching optimization algorithm, allowing it to overcome the constraints imposed by the local optimal extreme value and improve. The solution's accuracy improves as the convergence speed increases. Figure 6 depicts a stable comparison between the intelligent CFLTS proposed in this paper and the traditional CFLTS.

As shown in Figure 6, the overall stability of the ITS designed in this paper for CFL is significantly higher than that of the traditional teaching system. The stability of the traditional teaching system is relatively high during the initial operation of the system but decreases as teaching resources are gradually increased. The constancy of the traditional teaching system gradually decreases, while the stability of the ITS designed in this paper achieves 90% of the initial experiment. The system stability has been maintained at more than 90% due to the gradual increase of teaching resource data. This demonstrates that the intelligent CFLTS proposed in this paper has strong performance and can effectively improve teaching quality. Figure 7 depicts a time comparison of the intelligent teaching system and the traditional teaching system, which were divided into eight groups to obtain data on teaching CFL resources.

Figure 7 shows that at the start of the experiment, the time difference between the ITS and the other was significant. The traditional teaching system for obtaining CFL teaching resources is relatively small. However, as a result of each group's experiments, the time it takes for the traditional teaching system to obtain teaching resources for CFL is gradually reduced. The time it takes to obtain teaching resources data for the ITS of CFL proposed in this paper gradually decreases. The shortest time to get teaching data on CFL is 12 seconds. This demonstrates that the ITS proposed in this paper can efficiently improve student learning efficiency and teaching quality.

6. Conclusions

In the present educational improvement environment, the Chinese ITS is becoming progressively essential as a foreign system. In China, there have been few achievements in this area and even limited technology that can be utilized in the classroom. This area, which has a lot of potential for expansion, deserves more examination and discussion. Further education is needed to better understand the mechanisms that impact learning since the process of learning and the variables that complement it are all so numerous and intricate. As a result, process improvement is a must. Learning event categorization, documentation, and assessment approaches are a complex interaction of educational activities, student characteristics, and instructional methodologies. The demand for a scientifically designed and fully functional ITS for CFL is gradually increasing as the number of Chinese learners grows and intelligent mobile terminals become more popular. As a result, this paper proposes an intelligent CLTS, which takes into account the systematicity of Chinese as a second language, learning characteristics, and teaching strategies, as well as learner needs, in order to conduct an in-depth study on the design of an efficient is intelligent CLTS. The proposed internet-based CLTS model can alter students' learning methods. Those who assess students' learning levels, skills, learning styles, and other student status and characteristics and provide data for teaching and expert modules. Simultaneously, allowing it to provide personalized learning resources and environments for students improves the intelligence of the CFL and ITS. Educating students according to their abilities is highly practical.

Data Availability

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The author declares that there are no conflicts of interest for the publication of this paper.

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Research Article

Development and Application of MOOC System for English Intercultural Communication Courses Using Neural Network

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Presently, many researchers are focusing on the English intercultural communication course. However, these courses face serious challenges, such as individual student variances in conventional English cross-cultural teaching, fostering students' cross-cultural communication abilities, and enhancing teaching quality. These problems need to be solved; therefore, this paper aims to explore the development and application of the Massive open online courses (MOOCs) system in the English cross-cultural communication course based on neural networks. Firstly, the overall function modules of the MOOC system for the English intercultural communication courses are described, with emphasis on the student function module, teacher function module, administrator function module, and system database design of the MOOC system. Second, the MOOC system's teaching technique in an English intercultural communication course is based on a genetic algorithm, and the MOOC system's teaching quality index in an English intercultural communication course is chosen using principal component analysis. We conducted several tests to demonstrate that the MOOC system of the English intercultural communication course using the neural network suggested in this work is resilient and may successfully increase teaching quality. The experiment proves that the MOOC system of the English intercultural communication course based on the neural network developed in this paper has efficient results as compared to existing studies. In addition, it can effectively improve the teaching quality and can train students' intercultural communication skills and their ability to adapt to intercultural communication.

1. Introduction

In recent years, many scholars around the globe have carried out research and discussion based on the theory of cross-cultural communication ability. English cross-cultural communication ability includes both cross-cultural and communication abilities. Among them, the English intercultural courses are designed to prepare English learners to have a strong awareness of English culture and be able to critically assess the similarities and contrasts between their own culture and foreign cultures. The primary goal of English communicative competency is to develop high-quality and high-level skills, so that they can speak successfully with foreigners and have a certain level of cultural confidence. Besides that, the demand for high-quality skills in the social environment has grown up due to the fast expansion of the social networks and social economy. Yet, even at universities and colleges, there are certain issues with the teaching approach of English intercultural communication programs. They are unable to effectively utilize available instructional materials to improve students' overall growth. Since new technologies and web application platforms arise regularly, they have been utilized and enhanced in all aspects of our everyday environment [1]. Furthermore, the network's use in education has steadily increased and begun to be used in the teaching of English intercultural communication programs, which has undermined the conventional face-to-face teaching style [2].

Web-based interactive education is a form of learning that blends system resources with conventional teaching

techniques. The benefits of web-based cooperative learning have been more apparent with the entrance of the web 2.0 age. It is of considerable importance for increasing students' learning techniques, cooperation capability among pupils, and innovation skills [3, 4]. By merging the web-based cooperative learning paradigm with the conventional face-to-face teaching technique, this innovative learning style has significantly encouraged the change of the existing teaching paradigm. It can enhance the teaching environment in a variety of ways, including increasing students' enthusiasm for learning and increasing their learning performance [5]. As a result, the web-based cooperative education paradigm has significant theoretical implications for improving individual capacity and social advancement. Therefore, numerous online learning tools and forms of communication have evolved progressively in the existing social context of network infrastructure and teaching demands [6]. Google is among the quickly rising Internet powerhouses in the twenty-first century, offering cloud storage to Internet customers. Google Scholar, Google Earth, and Google Maps services are extensively utilized worldwide, offering considerable ease to people's lives, studies, and business [7]. The MOOC online learning system is a network platform with huge online courses available based on online teaching that also expands students' education pathways at all levels. However, the management of these platforms necessitates a high level of skill and money, making them challenging to establish and manage in institutions [8]. This study uses English teaching innovation as an example and proposes an innovative English teaching method focused on the Google collaborative platform and MOOC platforms to give students a different type of easy, comprehensive, and effective learning channels. This research will set the groundwork for advancing educational reform and organization effectively and efficiently in the classroom.

With the aforementioned rapid growth of Internet technology, this research formulates approaches based on the status of students' English knowledge in intercultural communication classes. It uses the students' English learning characteristics as a foundation to assist students in learning English intercultural communication effectively. In addition, we have developed a MOOC system for English intercultural communication classes based on neural networks. The MOOC system replaces traditional face-to-face teaching with online classroom learning. MOOC system is also a new development in distance education. People do not need to carry out aggregated classroom learning activities in the same place and time as traditional ones. It takes the form of open educational resources. It offers several advantages, including vast openness and scales, and has steadily developed a major component of modern investigation. The innovations of this paper are as follows:

(1) Explain the overall functional modules of the MOOC system in English intercultural communication course, with emphasis on the student and teacher functional modules, administrator functional modules, and system database design of the MOOC system. The initial weights of the neural network are optimized step by step based on the genetic algorithm, which can efficiently decrease the feature dimension and increase the effectiveness of students in learning English cross-cultural communication.

(2) Compared with the traditional English intercultural communication teaching system, the MOOC system has better overall robustness, can effectively improve the teaching quality, and can cultivate students' intercultural communication skills and their ability to adapt to intercultural communication.

The rest of this paper is organized as follows. Section 2 highlights the related work of national and foreign researchers. Section 3 explains the MOOC system for the English intercultural communication course. Section 4 describes our planned MOOC system. Section 5 presents the experimental work and testing of the proposed system, and Section 6 concludes the study.

2. Related Work

Large-scale open courses have revolutionized digital education around the world, enabling people ready to obtain information to acquire well-known courses online, and making the certification a reality. Zhang's particle swarm optimization and support vector machine-based assessment model of the teaching effect of English intercultural communication may significantly enhance accuracy. Based on the relevant theory, the paper of [1] establishes a multi-index evaluation system of the teaching effect of English intercultural communication with English teachers and students as the main body and takes the evaluation index of the teaching effect of English intercultural communication as the input sample of Support Vector Machine to achieve the evaluation of the teaching effect of English intercultural communication. The particle swarm optimization approach is used to solve the support vector machine kernel function and the regularized optimal solution, as well as to optimize the SVM classifier evaluation process. The experimental results show that the accuracy of this method is higher, but the overall testing time is longer. To improve the evaluation accuracy of English intercultural communication teaching quality, Chuai Q inputs parameter weights and implied layer bias coefficients from the initial state of the model and applies the GWO-ELM algorithm to the MOOC system quality evaluation of English intercultural communication course.

The work in [9] establishes an evaluation index system for the quality of English intercultural communication teaching based on teachers' qualities, attitudes, modes, effects, and contents and then takes the evaluation index and the quality type of English teaching as the vector of input and output of ELM model. Therefore, a teaching quality evaluation method based on the GWO-ELM model for the MOOC system of English intercultural communication courses is constructed. Experiments show that this model can effectively enhance the evaluation correctness of teaching quality of English intercultural communication compared with other models, but the improvement of

teaching quality is not obvious. To effectively realize the accurate evaluation of English cross-cultural communication teaching, Wang Y improves the teaching dilemma of English teaching in cross-cultural communication.

The early work of [10] constructs a GWO algorithm with optimal click-through and random convergence factors, establishes an evaluation index of English cross-cultural communication classroom teaching by using the analytic hierarchy process and cross-cultural competence, combines the rating score data and competence level of English cross-cultural communication teaching as input and output vectors, and constructs an evaluation model of English cross-cultural communication classroom teaching based on IGWO-SVM. The IGWO-SVM model has a very high convergence rate and stability in the evaluation of English intercultural communication classroom teaching, but it has the problem of inefficient English intercultural communication learning. With the deepening of the integration of information technology and education, the MOOC system plays an important role in network teaching and mixed teaching. The complexity of the MOOC-based educational environment for English intercultural communication is interconnected and interactive.

The construction of a mixed-mode of English teaching is a new form and feature of the development of English education in China. It can effectively promote the harmonious development of the teaching environment, but the process of this method is complex, resulting in lower learning efficiency [11]. Therefore, this paper aims to explore the development and application of the MOOC system in the English cross-cultural communication course based on neural networks.

3. MOOC System for English Intercultural Communication Course

3.1. Analysis of MOOC System Function Modules. A massive open online course (MOOC) is a public web-based online training product developed for huge groups of students from various locations. It might be based on a university or college course. Whereas these courses may not often provide academic credit, they may provide a certification, improve work possibilities, or lead to additional study. MOOCs are mostly utilized for higher education and job growth. However, as a result of the coronavirus outbreak, several public schools and undergraduate degree programs have made MOOCs the new standard. The MOOC system of English intercultural communication course is divided into login control module, intercultural communication course resource management module, intercultural communication interactive learning module, and system management module according to the system requirements. Figure 1 explains the functional modules of the MOOC system for English intercultural communication courses.

In the figure, the login control function is mainly used to register the user in the English cross-cultural communication MOOC system. The system function responds to the access of user rights. If the user fails to recall the login key, the login key can be altered by key management, and the user key data of the background catalog can be updated automatically. Resource management functions can be divided into English cross-cultural communication course management and other teaching resource management [12, 13].

Online teaching function: administrators or teachers in the MOOC system can publish and update announcements of English intercultural communication courses in the News Center, other college news, and online teaching links and provide students with access and reference and learning.

Interactive learning function: the interactive learning function of the MOOC system includes the functions of discussion and answer in an English cross-cultural communication course. Interactive learning is a very typical feature of a MOOC system. It uses the interactive learning function to complete the formation of a learning network among learners and improve the communication between instructors and pupils.

System management functions: MOOC system has some characteristics such as plainness, sharing of resource, and multiuser right of entry. Data security issues and role differences need to be considered. For this reason, system management function settings in MOOC systems include user info administration, role administration, and security administration functions [14, 15].

3.1.1. Student Module. This module assists the students in obtaining knowledge in a more organized and organized manner. That unit is one of the instructional resources that have been thoroughly and systematically organized. In addition, it contains a series of prepared learning opportunities meant to assist students in comprehending specified educational objectives. Based on the module analysis of the above MOOC system, the MOOC system can be divided into the foreground and background structures. The foreground is specific for English cross-cultural communication students, while the background is for administrators to achieve and retain the MOOC scheme. Based on student membership analysis, the MOOC system of English cross-cultural communication is distributed into student functional diagrams as revealed in Figure 2.

In the figure, on the first page of the website, students who have registered for the MOOC system in the English intercultural communication course can log on to the system page by entering their username and password in the login interface. News Center: all students who access the MOOC scheme can access and browse the news information in the MOOC system [16, 17].

(i) Course Center: students can click on the online learning in the MOOC system, carry out online learning, or evaluate the learning courses after they log on to the MOOC system.

(ii) Resource Center: after students log on to the MOOC system, they can search through keywords for English intercultural communication, courseware, or

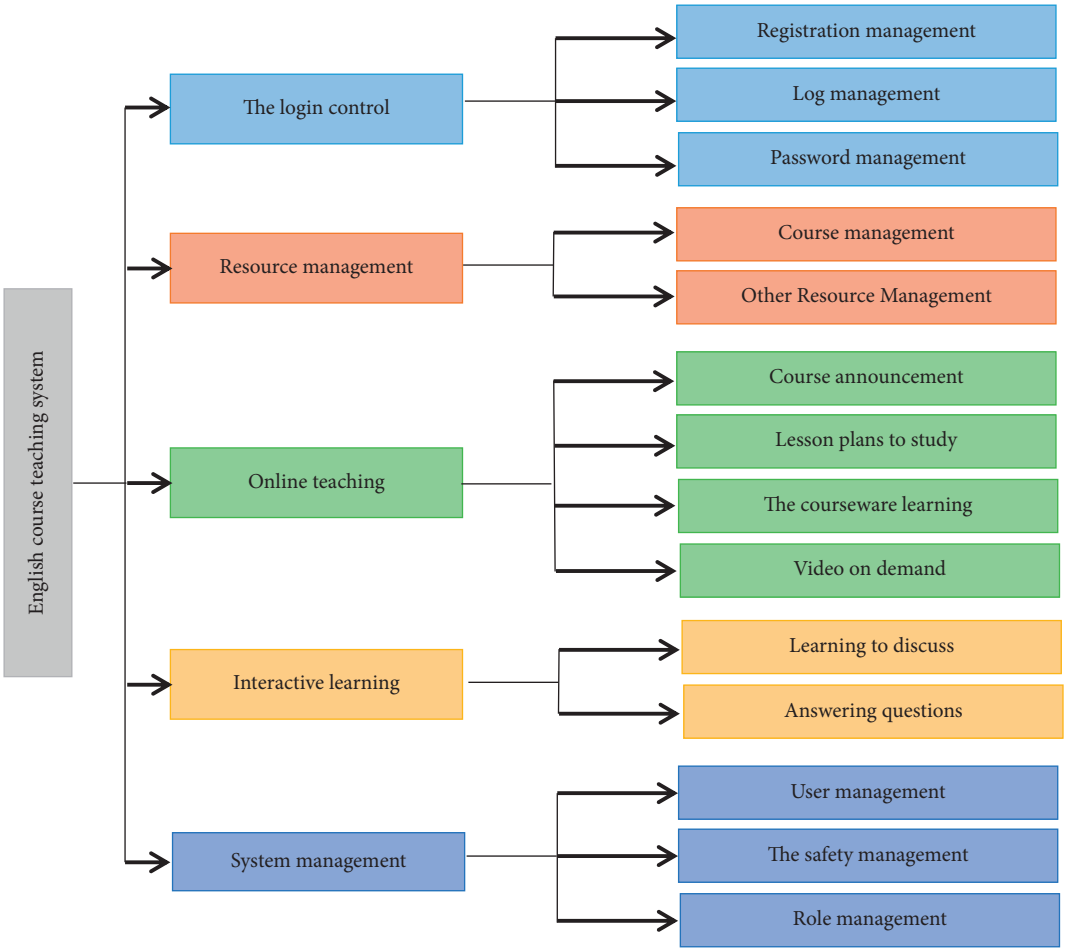

Figure 1: Functional modules of MOOC system for English intercultural communication.

other teaching resources they need and download them.

(iii) Personal Center: in the Personal Center module, pupils can see individual info, exercise plans, and learning development, post topics and comments, and access chat rooms with links.

3.1.2. Teacher Function Modules. This module enables instructors to draw direct connections to curriculum standards and guidelines, either through hyperlinks if they are available online or by stating the standards in the Learning Goals section. MOOCs can provide a chance to investigate, gather, produce, and create new information and skills. As a result, pre-service or in-service educators can cultivate a more diverse innovative perspective that enhances their educational position. Based on the analysis of the teachers' users, the MOOC scheme can be distributed into the teachers' function modules shown in Figure 3.

In the figure, the teacher module is divided into 5 units such as personal center, resource center, course center, News center, and Homepage. The details of each unit are discussed one by one here:

(i) Homepage: the primary goal of a homepage is to guide users through our system; thus, it is critical that our visitors could do so easily. Make a clear distinction between the choices and have a strong idea of what is underneath the connections. Teachers with rights of teacher enter usernames and passwords in the interface of the MOOC system for English intercultural communication courses. After successful login, the first page of the MOOC system for the English intercultural communication course appears.

(ii) News Center: teachers who have access to the English intercultural communication MOOC scheme can access and peruse the content in the system's news unit. It can also publicize the English intercultural communication training and other relevant information.

(iii) Course Center: teachers can publish and view the courses after they log on to the MOOC system of the English intercultural communication course and answer the questions raised by students [18, 19].

(iv) Resource Center: by making knowledge available, resource centers may help with a variety of active learning. After logging in, teachers can access and upload learning resources to the MOOC system. Personal Center: teachers have a personal center module that allows them to access the content they

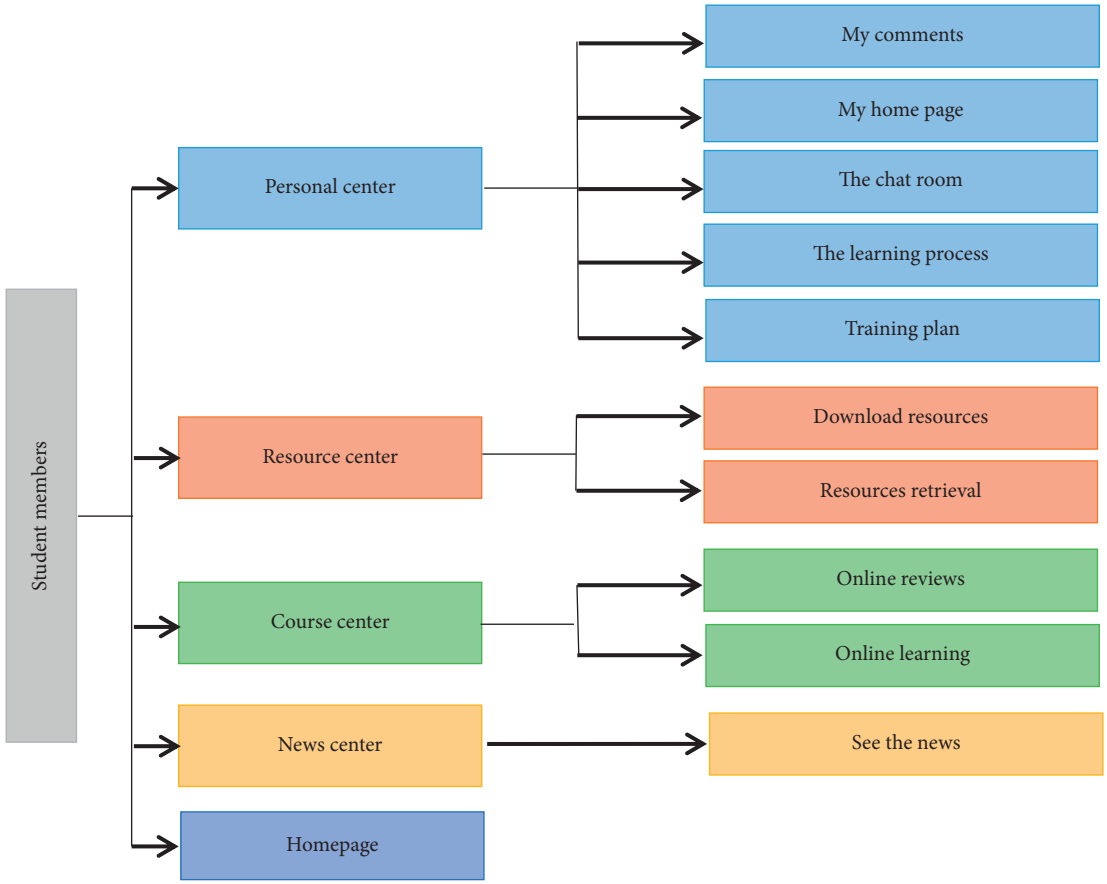

Figure 2: Student user function module diagram.

have published as well as the associated courses and teaching tools. Teachers can also access chat rooms.

3.1.3. Administrator Functions. Based on the functions of administrators, the MOOC system of English intercultural communication courses is divided into functional modules as shown in Figure 4.

The Administrator module, as shown in the diagram above, is made up of seven units: homepage, user management, news management, course administration, teaching supervision, resource management, and system maintenance. This section will go through each of these units one by one.

(i) Homepage: after the administrator logs on to the MOOC system page of the English intercultural communication course, after entering the username and password, the first page of the administrator's website appears and clicks into the administrator's background management interface.

(ii) User management: the administrator of MOOC system can effectively manage ordinary users, add or delete user information, and modify some operations.

(iii) News management: administrators have the right to publish campus news and bring up-to-date and achieve the campus news as per to the progress of English cross-cultural communication teaching.

(iv) Course management: administrators should audit video courses published to the system for students to study for characteristics such as file format, size, and legitimacy of the uploaded instructional videos. Furthermore, following approval, administrators should update the list of front-end display videos according to the success of English cross-cultural communication education [20, 21].

(v) Resource management: resource management is the process through which firms properly manage their numerous resources. These resources can be both intangible and tangible. It entails planning, so that the appropriate resources are allotted to the appropriate tasks. Plans and budgets for people, programs, technology, and supplies are all part of resource management. In our system, resource management is roughly the same as the above course management.

(vi) Teaching supervision: MOOC system administrators should not regularly monitor and inspect the learning of students, timely discover the information and statements published in the system that is not related to English intercultural communication courses, and punish the serious cases.

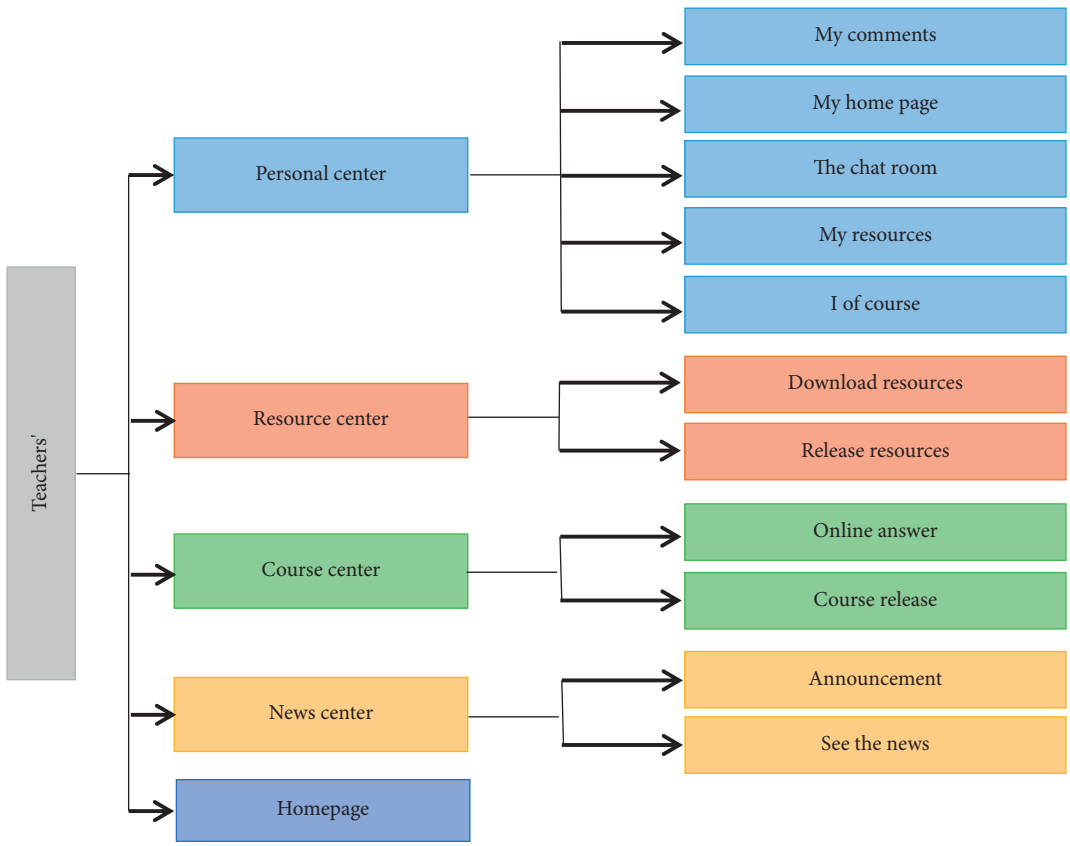

Figure 3: Functional structures of teacher users.

(vii) System Maintenance: it is an overall term for several types of computer maintenance necessary to keep a system working. Corrective and preventative maintenance are the 2 fundamental components of maintenance services. MOOC system administrators must maintain the MOOC system at irregular intervals, find out problems in time, and analyze and solve the problems thoroughly so as to make the MOOC system of English intercultural communication course run stably.

3.2. Database Design. The MOOC system for English intercultural communication courses includes many databases and user data, so the amount of data in the MOOC system is relatively large. The data description of the English intercultural communication course, as well as how the data is arranged and stored, will have a direct impact on the database system's efficiency. As a result, MOOC system databases must emphasize data integration and various types of data analysis. The MOOC system for English intercultural communication courses includes user information as well as a variety of other data such as teaching courses, course catalogs, system keywords, and learning levels. When students or teachers log into the MOOC system, a large amount of operational data is created, as illustrated in Table 1.

4. Proposed MOOC System for English Intercultural Communication Course Based on Neural Network

In the neural network, the output layer is the weighted amount of the input English cross-cultural communication course data after using the activation function of the hidden layer. A radial basis function (RBF) is a form of neural network that is effective when data is categorized in a nonlinear manner. They operate by adding the Radial basis function as a neuron and matching input data to training data. The RBF and dynamic weights are the solutions to the neural network, and the radial basis function is expressed by

$$R\left(x_p - c_i\right) = \exp\left(-\frac{\left\|x_p - c_i\right\|^2}{2\sigma^2}\right). \quad (1)$$

Here, $\|x_p - c_i\|$ denotes the $x_p - c_i$ norm, and x_p denotes the input sample data in the output layer of the MOOC system. In addition to the above, c_i denotes the radial basis function center, while σ denotes the width of RBF.

Equation (2) expresses the neural network output after specifying the network weights and radial basis function parameters of the MOOC system.

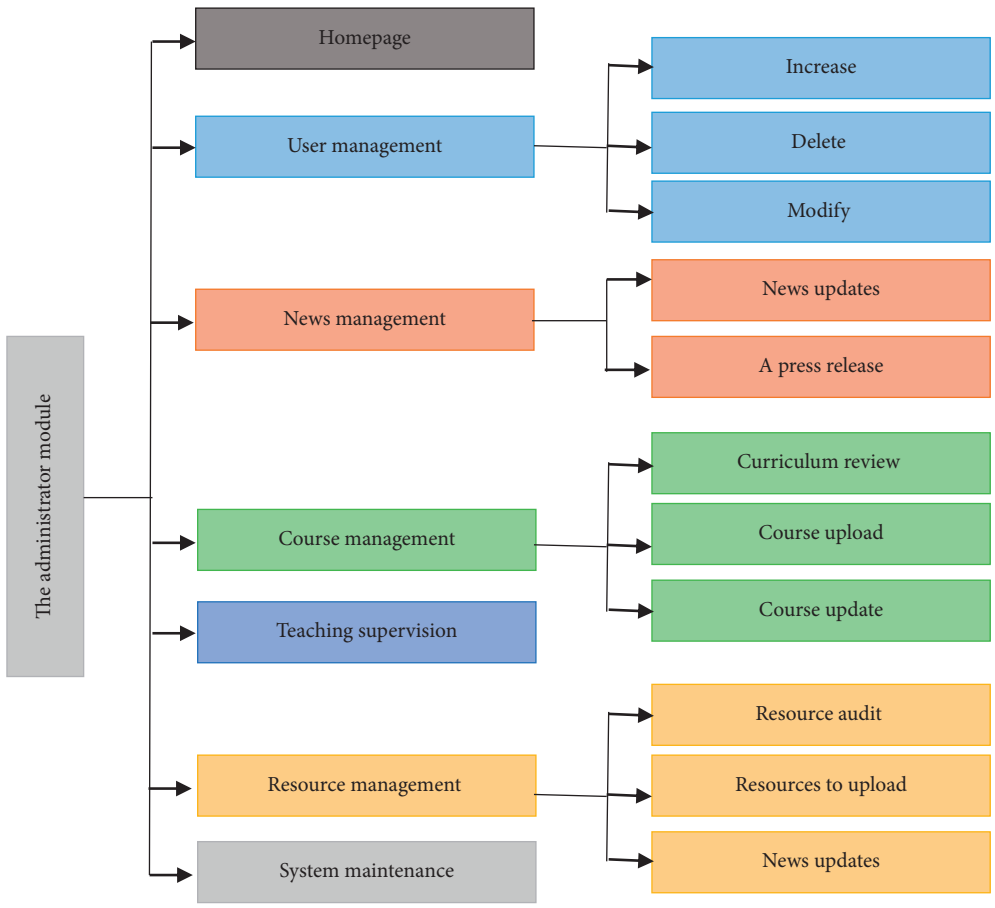

Figure 4: Administrator function module diagram.

Table 1: System user data table.

The field name	Type	Primary key or not	The length of the
The class	Char	No	20
The name	Char	No	20
Gender	Char	No	20
The phone number	Char	No	20
E-mail	Char	No	30
WeChat	Char	No	20
QQ	Char	No	20
Major	Char	No	30
Department	Char	No	20
Password	Char	No	20
ID	Int	Is	4

$$y_i = \sum_{i=1}^{h} \omega_{ij} \exp\left(-\frac{\left\|x_p - c_i\right\|^2}{2\sigma^2}\right), j = 1, 2, \ldots, n. \quad (2)$$

In the above Equation, ω_{ij} signifies the indirect layer and output weight of MOOC structure. Based on the procedure of solving the neural network, the process of network optimization is to bring up-to-date the dynamic weight and radial basis function center and width gradually according to the training data of the English intercultural communication course until the neural network completes the approximation of the nonlinear function [22, 23].

The smaller the change amongst the network output value and the predictable value is, the more improved the matching chromosome is. The inverse of the error, which takes the expected output and individual mean square deviation in the population, is a function of the fitness of the genetic algorithm operation, expressed by

$$E = \frac{1}{\sum_{k=1}^{N} (T_k - Y_k)^2}. \quad (3)$$

In the aforementioned Equation, N denotes the number of chromosomes in the population of the MOOC system; y denotes the real output value of the MOOC scheme, and T denotes the predictable production value of the MOOC scheme.

Based on chromosome b_i, if the function value of MOOC scheme fitness is E_{b_i}, the optional probability can be calculated using

$$P(b_i) = \frac{E_{b_i}}{E}. \quad (4)$$

In the above Equation, E denotes the fitness function value of the chromosome population in the MOOC scheme. In comparison, chromosomal fitness influences the likelihood of chromosome selection [24, 25].

A biological operator called crossover is being used to change the coding of a chromosomal or genes from one

generation to another. Reproduction is achieved by crossover. 2 strings are selected at random from the selection pool to cross to generate superior progeny. The technique used is determined by the Encoding Scheme. Crossover operation is an important core of genetic algorithm optimization. In this paper, the setting of crossover probability of genetic evolution is calculated using

$$P_c' = \begin{cases} P_{c\max}, & E_{\max} \prec E_{\text{mean}}, \\ P_{c\max} - \dfrac{P_{c\max} - P_{c\min} \times \text{iter}}{\text{iter}_{\max}}, & E_{\max} \prec E_{\text{mean}}. \end{cases} \tag{5}$$

In the equation mentioned above, $E_{\max}$ denotes the extreme fitness function value of 2 chromosomes coming up for crossover in MOOC scheme, while E_{mean} denotes the function mean of chromosome fitness in MOOC scheme. Similarly, $iter$ denotes the amount of repetitions of genetic algorithm evolution, $itet_{\max}$ denotes the maximum amount of repetitions of genetic algorithm, and $P_{c\max}$ denotes the set crossover probability value.

The mutation probability is being used to evaluate whether or not to modify a gene every moment it is examined. As a result, small numbers guarantee that not many changes are assessed at the same time; however, this will rely on the set of genes for each member of a population. Depending on the way of setting the crossover probability, the setting of the mutation probability is carried out in

$$P_m' = \begin{cases} P_{m\max}, & E \prec E_{\text{mean}}, \\ P_{m\max} - \dfrac{P_{m\max} - P_{m\min} \times \text{iter}}{\text{iter}_{\max}}, & E \geq E_{\text{mean}}. \end{cases} \tag{6}$$

According to the Equation above, once the function value of chromosome fitness is lower than the mean, the set of mutation probability is smaller, which can preserve the better chromosome individuals and increase the local optimization ability of the genetic algorithm.

PCA improves in data interpretation although it may not always detect key patterns. The principal component analysis (PCA) technique reduces the computational difficulty of high-dimensional data while preserving themes and relationships. It achieves this by reducing the data to a lower dimensionality that serves as feature descriptions. PCA can comprehensively analyze the teaching quality of MOOC system in English intercultural communication courses, remove redundant elements, and generate new indicators for MOOC system teaching [26–28]. Set up a MOOC system for the original English intercultural communication course as an indicator set of teaching quality. It can be calculated using

$$X = \left(X_1, X_2, \ldots, X_p\right). \tag{7}$$

Here, p specifies the amount of MOOC system teaching indicators, and there is a big difference in data between the teaching quality indicators of English intercultural communication. In order to effectively reduce the impact of large data on small data, standardized processing of collected English intercultural communication data must be carried out using

$$\overline{x}_{ij} = \frac{x_{ij} - \overline{x}_j}{s_j}. \tag{8}$$

After standardization of MOOC system teaching quality indicators for English intercultural communication courses, the matrix of index correlation coefficients is calculated as

$$R = \left(r_{ij}\right)_{p \times p}. \tag{9}$$

In Equation (9), r_{ij} denotes the correlation coefficient between the i teaching quality sample and the j index.

The characteristic equation $\lambda u = Ru$ of MOOC system is established, and the eigenvalues and eigenvectors of the characteristic equation are calculated using (10) and (11), respectively.

$$\lambda = \left(\lambda_1, \lambda_2, \ldots, \lambda_p\right), \quad \lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_p \geq 0, \tag{10}$$

$$u = \left(u_1, u_2, \ldots, u_p\right). \tag{11}$$

The cumulative variance contribution to the teaching quality index components of MOOC system of English cross-cultural communication course is expressed as

$$\xi = \sum_{i=1}^{P} \alpha_i. \tag{12}$$

In the (12), α_i signifies the involvement of the i key module in the teaching quality index of MOOC system. The selected indicators based on principal module investigation are used as the vector of the new characteristics of English teaching quality, which can efficiently reduce the characteristic dimension and improve the efficiency of students' learning English cross-cultural communication, so as to complete the development and application of MOOC system of English cross-cultural communication course based on neural network.

5. Experimental Result and Testing of System Function

5.1. Experimental Result. The rationality of the development and application of MOOC system for English cross-cultural communication course based on neural network is verified through experiments. Table 2 shows the experimental parameter settings.

This paper compares and analyzes the teaching effect of the method proposed in literature [11] with the MOOC system of English cross-cultural communication course based on neural network. Based on students' score of 500, the teaching scores of the two methods are compared, which is shown in Table 3.

As can be seen from Table 3, when the number of students is 200, the score obtained by the system under the method proposed in document [11] is 310; when the number of students is 1000, the score obtained by the system under the method proposed in document [11] is 270; when the

Table 2: Parameters of experimental work.

Project	Model
Server for host	IPC-610L
Central processing unit (CPU)	i5 9400F
Micro server	AMD opteron X3216
Storage	8 GB

Table 3: Comparative analysis of scores obtained by MOOC system under the two methods.

Number of students/person	In this paper, methods	Methods of reference [11]
200	452	310
400	486	290
600	489	286
800	476	276
1000	479	270

same number of students is 200, the lowest score obtained by the system under the method proposed in this paper is 452; when the number of students is 600, the highest score obtained by the system using the method proposed in this paper is 489 points. It is concluded that the MOOC system of English cross-cultural communication course based on neural network can better stimulate students' interest in learning English and improve their ability to adapt to cross-cultural contact. Figure 5 shows the teaching efficiency comparison between the traditional English cross-cultural communication course teaching system and the neural network-based English cross-cultural communication course MOOC system.

By analyzing the Figure, it can be seen that when the time is 10s, the teaching efficiency of the traditional English cross-cultural communication course teaching system is 59%, while the teaching efficiency of the neural network-based English cross-cultural communication course MOOC system is 84%, and when the time is 30 s, the teaching efficiency of the traditional English cross-cultural communication course teaching system is 60%, the teaching efficiency of MOOC system based on neural network is 95%. It can be seen that, at the beginning of the experiment, the teaching efficiency of the two systems is not very high, but because the MOOC system adopts neural network, the system quickly returns to the normal mode, which shows the rationality of the MOOC system of English cross-cultural communication course based on neural network. Taking the robustness of the system response as the test index, Figure 6 shows the comparison of the robustness test results between the traditional English intercultural communication course teaching system and the English intercultural communication course MOOC system based on neural network.

As can be seen from Figure 6, the MOOC system of English cross-cultural communication course based on neural network has good robustness, response ability, and convergence performance, while the traditional English cross-cultural communication course teaching system produces large oscillation, resulting in poor overall stability of the English cross-cultural communication course

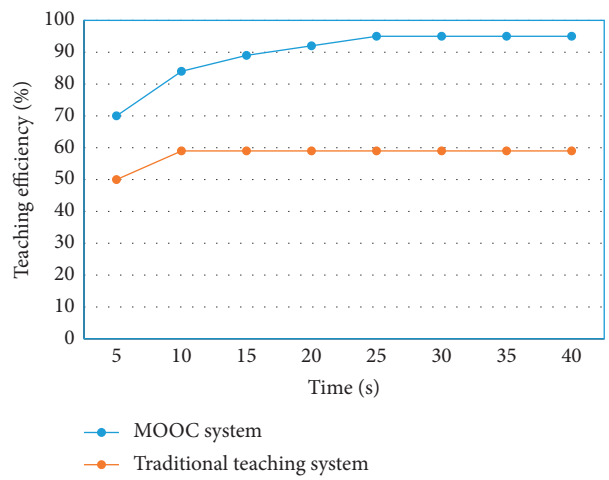

Figure 5: Comparative analysis of teaching efficiency of different systems.

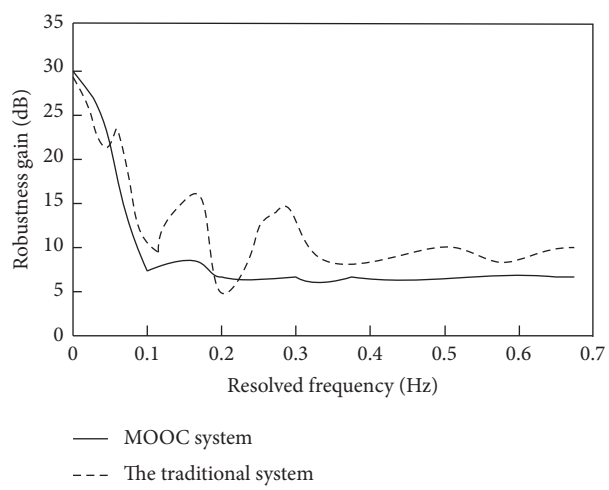

Figure 6: Comparison of robustness test results under different systems.

teaching system. The method proposed in this paper effectively improves this problem and improves the stability of the MOOC system. Figure 7 shows the comparison of teaching quality improvement between the traditional English intercultural communication course teaching system and the neural network-based English intercultural communication course MOOC system.

Through the analysis of above Figure, it can be seen that although the traditional English cross-cultural communication course teaching system has also improved the teaching quality, the maximum is not more than 40%. At the beginning of the experiment, the MOOC system of English cross-cultural communication course based on neural network has improved the teaching quality by 53%, which is higher than the traditional teaching system. With the gradual improvement of English cross-cultural communication teaching resources, the teaching quality of English cross-cultural communication is also gradually improved, which shows that the MOOC system in this paper can

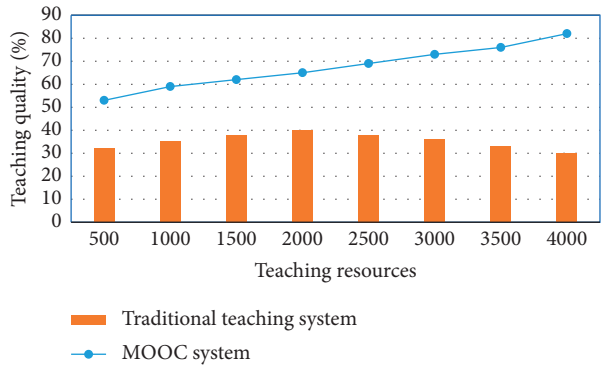

Figure 7: Comparison of teaching quality improvement under different systems.

effectively cultivate students' cross-cultural communication skills, their attitude towards different cultural understanding, and their ability to adapt to cross-cultural contact.

5.2. Test for System Function. The performance testing item involves the full study's validity, comprising stability analysis, dependability, throughput and workload, etc. Various performance testing techniques are utilized to emulate the system's real-world application situation. The performance state of the system may be acquired by the study of various factors, such as the usual condition of scheme use, the unusual load of a control system, recorded max value, and lower peak value. Pressure testing and load tests are common test techniques. Figure 8 depicts the system's efficiency test scenarios.

In this work, the scheme time of response is investigated by varying the number of simultaneous users and the number of queries. The testing is performed with 50 people on the Internet, 100 people on the Internet, 150 people on the Internet, and 200 people on the Internet. The test outcomes demonstrate that the system performs consistently, and the scheme load is reduced during operations. The quicker the system responds, the smaller the response time is, and the average response is even less than 2 seconds whenever the number of simultaneous users is fewer than 200. In general, this type of process uses less system resources and completely meets the requirement that the time of response of the 200 users' basic operating system is fewer than 3 seconds. Simultaneously, the system is put in a hostile situation for the scheme boundary test. The login page, registration, and so on are all part of the assessment object. The system performs well and can satisfy the design specifications.

5.3. Test for System Response Time. Time of response relates to the overall amount of time that users spend sending requests and receiving services once the system responds. A system's reaction time is the overall time it takes to transfer the initial byte from the client to the last byte. Scheme ability testing: the reaction time and processing capacity of the system are used to determine system capacity. The system throughput per unit time is primarily measured, and the

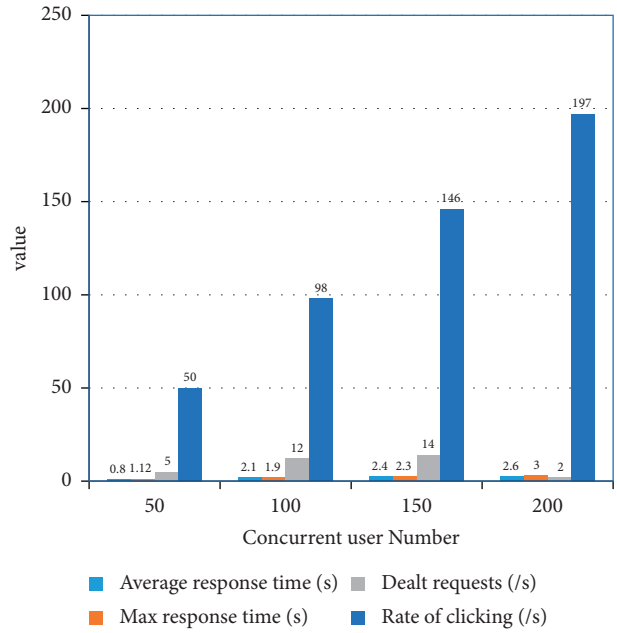

Figure 8: System's efficiency.

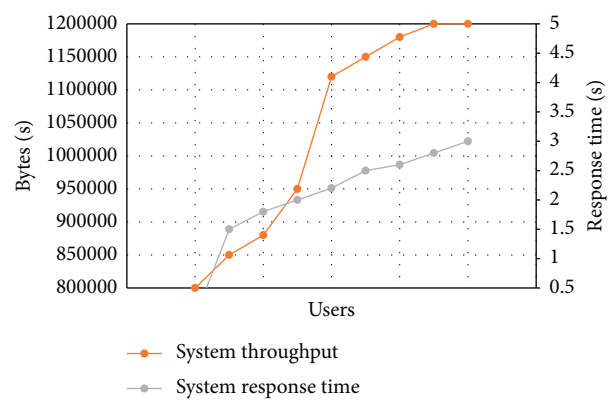

Figure 9: Handling capability test result.

system's handling capacity is then estimated based on the traffic volume. The handling capability test result of the system established in this work is shown in Figure 9.

As per the figure above, the system can do seven activities every minute. The system's response time will rise as the number of network users grows. The system's processing capability is relative to the amount of system users; however, as the number of users grows, the system's processing capability will eventually decline.

6. Conclusions

Keeping in mind the value of education, this study combines English teaching ideas and methods using the MOOC system of neural network-based intercultural communication courses to improve the learning of English knowledge points. MOOC courses are not limited to university-specific term and semester samples. So, they can start at any moment and go on at any time. As a result, MOOCs are attractive for

short-term courses that focus entirely on a topic or for courses that can lead to a better understanding of the academic field. The learning model teaches English international communication skills using neural networks. It enhances the interesting nature of English cross-cultural communication and helps improve the teaching effect and quality of English cross-cultural communication.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest for publication of this paper.

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Research Article

Prediction of Cognitive-Behavioral Therapy using Deep Learning for the Treatment of Adolescent Social Anxiety and Mental Health Conditions

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Cognitive-behavioral therapy is a type of psychosocial intervention which aims to reduce the mental health conditions like depression, anxiety disorder, and others. Similarly, deep learning is a type of machine learning and artificial intelligence that imitates how humans gain certain types of knowledge. In this paper, deep learning has been used to effectively alleviate teenagers' social anxiety and improve their social ability and the quality of social relations. It aims to conduct an in-depth study on the diagnosis and treatment of cognitive behavior therapy in teenagers based on deep learning. First, it constructs the cognitive behavior diagnosis and treatment evaluation system of adolescent social anxiety and divides the system function into functional, structural, and database design. Then, the correlation prediction model between cognitive behavior therapy and adolescent social anxiety is constructed based on a multiobjective evolutionary algorithm. The risk and protective factors in adolescent growth are screened from the perspectives of people, family, school, and society. The fuzzy itemset support of different factors is defined. The vector of adolescent social anxiety expression index's weight is calculated. The subjective and objective factors of social anxiety in adolescents are extracted based on the grey correlation degree. The correlation prediction model between accurate cognitive behavior therapy and adolescents' social anxiety is established to complete the prediction research, diagnosis, and treatment effect. Simulation experiments show that the proposed method has good feasibility and high prediction accuracy. It can effectively alleviate the social anxiety of teenagers.

1. Introduction

One of the most frequent types of pediatric diseases is anxiety disorders. According to research, juvenile anxiety disorders are linked to social and family factors. If left untreated, academic impairment is likely to remain, and children are more likely to acquire anxiety problems later in adolescence and age [1]. Clearly, being able to intervene early in the treatment of these illnesses would be advantageous. Promising cognitive-behavioral therapy (CBT) for childhood anxiety disorders, such as social phobia, separation anxiety disorder, and generalized anxiety disorder, has been developed over the previous two decades [2, 3]. According to these studies, CBT can be effective for various problems when used alone or in conjunction with sertraline and when given individually or as a family treatment. Despite the fact that at least eight early studies have shown the efficacy of approaches such as in vivo desensitization, filmed, live, and participant modeling, graded exposure, reinforced practice, and verbal self-instruction in treating fears or specific phobias in preschool- and kindergarten-age children, protocols for treating the other major childhood anxiety disorders have primarily been evaluated in school-age children and adolescents [4]. Although some studies lowered the age of inclusion to 5 or 6.12, they typically included a limited number of the youngest children (mean sample ages of 11.03 and 7.8 years, respectively) and did not look at the outcomes individually for this age group [5].

According to research from the 1950s and 1960s, 40–60% of people with panic disorder were unaffected or improved just a little. Although some of these publications found no significant change in participants after various periods, the results of retrospective studies conducted after the availability of approved anxiety drugs are also variable [6]. There is also a perception that younger children were not developed enough to benefit from cognitive-behavioral therapies. It may have contributed to the underrepresentation of younger children in trials using CBT protocols for severe childhood anxiety disorders. Recent research, however, has cast doubt on these beliefs. For starters, investigations have revealed that preschoolers develop chronic anxiety disorders at about the exact incidence as older children. Factor-analytic studies have indicated that preschoolers' symptom presentations are similar to those in older children. Moreover, numerous organizations have recently begun experimenting with CBT procedures for various anxiety issues in young children [7].

In the case of adolescents, relevant studies show that interpersonal skills and relationship quality are the main factors affecting teenagers' mental health [8]. Junior high school students are in the early stage of adolescence, which is a significant turning point in life. Some developed countries have a wide range of research objects for social anxiety. It has a very high incidence and comorbidity rate. It is one of the primary diseases that affect students' mental health in the adolescent stage [9]. It has an essential impact on adolescents' life, learning, personality improvement, and future development. Therefore, this paper explores teenagers' social anxiety in depth, hoping to use appropriate, feasible, and practical implementation methods to provide experience for alleviating teenagers' social anxiety, mental health education courses, and activities. It will promote teenagers' mental health, improve interpersonal communication, and increase social adaptability.

The innovations of this paper are as follows:

(1) We construct a cognitive behavior diagnosis and treatment evaluation system for adolescent social anxiety. Next, we built the correlation prediction model between cognitive behavior therapy and adolescent social anxiety based on a multiobjective evolutionary algorithm. Also, we established the correlation prediction model between accurate cognitive behavior therapy and adolescent social anxiety.

(2) We made a comparison with other prediction models to evaluate the effectiveness and novelty of our work. The proposed method can effectively alleviate teenagers' social anxiety and improve teenagers' social ability. Our work has much better performance as compared to existing work in terms of complexity and accuracy and is highly effective for alleviation of adolescent social anxiety

The rest of the research paper is organized as follows; Section 2 will explain all the related work linked to this research. Section 3 sheds light on the evaluation system of cognitive behavior diagnosis and treatment of adolescent social anxiety. Similarly, Section 4 elaborates on the predictive modeling of the relationship between cognitive-behavioral therapy and adolescent social anxiety based on deep learning. In addition, Section 5 explains the analysis of experimental results conducted in this research. Finally, concluding remarks have been described in Section 6.

2. Related Work

With the progress of the times, the emphasis on teenagers' psychological problems has gradually increased. An in-depth study on teenagers' social anxiety has been carried out, and some results have been achieved. It identified the potential categories of alexithymia and the relationship between social anxiety and depression to provide the basis for promoting the positive development of emotion and mental health of college students [10]. The Alexithymia Scale, social anxiety scale, and the self-rating depression scale of the center for flow survey were used to carry out a questionnaire survey. The relevant data were analyzed by profile analysis and logistic regression analysis. Logistic regression analysis showed that, after controlling the demographic variables, college students' good emotional expression and discrimination were negatively correlated with depressive symptoms and social anxiety. Relevant conclusions show that the alexithymia of college students is distributed according to categories. The potential categories are different from social anxiety and depressive symptoms. In the education related to mental health, schools should scientifically formulate specific programs for the cultivation and intervention of college students' emotional regulation ability to promote the positive development of college students' psychology. However, it should be noted that this method has not alleviated college students' social anxiety [11]. Firstly, this paper expounds on the impact of anxiety of mobile social media measures on teenagers' mental health, analyzes the influencing factors, and establishes a model. It enriches the integration of teenagers' behavior theory in psychology and puts forward targeted psychological counseling and related intervention programs for social media users. Using the model framework based on I-PACE theory, this paper analyzes the model elements of adolescent social media users from four dimensions to establish the relationship model of adolescent social media, analyze the interaction-driven relationship between different elements, and determine the path of linkage between factors. The cognitive behavior method is used to specifically intervene in social media and establish a scientific service and management system for teenagers' social media users, but this method has not alleviated the teenagers' social anxiety [12]. It mainly takes teenagers in the context of content-based social media as the research object and conducts an in-depth study on the main factors and the internal correlation mechanism between different factors influencing the formation of content-based teenagers' social media social anxiety.

From the perspective of the generation characteristics provided by content youth social media, taking the theory and calculation of expectation confirmation as the theory and basis, the theoretical research model is established with

the relevant theories of cognitive psychology and information behavior under the framework of social media. The data is obtained by questionnaire survey, and then the model is tested. The experimental results show that teenagers' expectation of confirmation will be positively affected by the content and service quality. In contrast, system quality will have little impact on teenagers' expectation confirmation. Teenagers' willingness to continue to use and perceive popularity will impact their stress perception. However, the intensity is easily restricted by the psychological elasticity of individual quality. Therefore, it does not improve teenagers' social ability [13]. Through group treatment of cognitive behavior, the effect of emotional regulation efficiency of adolescent patients with social anxiety was observed. Firstly, 61 adolescents with social anxiety were divided into CBGT (cognitive-behavioral group therapy) groups by lot for 12 weeks of treatment. There were 32 and 29 cases in the control group without any treatment. The social anxiety scale and emotion regulation self-efficacy scale were used to evaluate the social anxiety and emotion regulation efficacy of adolescent social anxiety patients. The two groups of adolescent social anxiety patients were scored. The results showed that, after 12 weeks of treatment, the score of the social anxiety scale of adolescents in the CBGT group was significantly lower than that before treatment and the self-efficacy of emotion regulation was improved compared with that before treatment. The difference between the control group and the 12th week was not statistically significant. The conclusion shows that CBGT can effectively improve the symptoms of adolescents' social anxiety and improve the self-efficacy of emotion regulation. However, due to the complex process, the treatment cycle is long [14].

3. Evaluation System of Cognitive Behavior Diagnosis and Treatment of Adolescent Social Anxiety

This section sheds light on the overall design of adolescent social anxiety cognitive behavior diagnosis and treatment evaluation system, functional, structural design of cognitive behavior diagnosis and treatment evaluation system for adolescents' social anxiety, and database design. It will help clarify the evaluation system of cognitive behavior diagnosis and treatment of the adolescent. The explanation is as follows.

3.1. Overall Design of Adolescent Social Anxiety Cognitive Behavior Diagnosis and Treatment Evaluation System. The design idea of cognitive behavior diagnosis and treatment evaluation system for adolescent social anxiety is to combine new computer technology with artificial intelligence and medical technology to build a human-computer interaction and intelligent evaluation system. It will realize the scientific and correct evaluation of adolescent social anxiety patients. Figure 1 shows the evaluation system of the B/S (Browser-Server) mode. In Figure 1, the client browser only undertakes less logical operations. Most of the operations in the system functions are realized through the

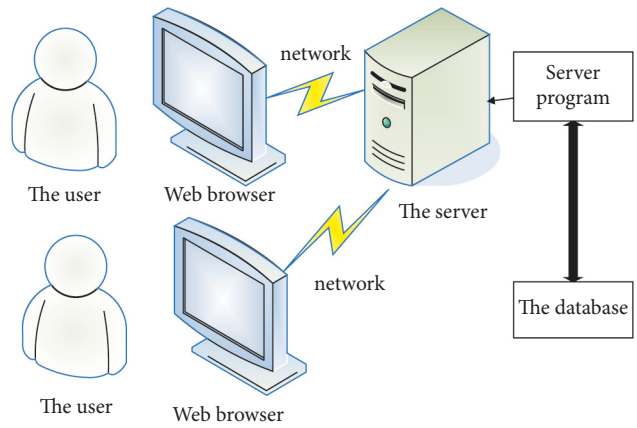

Figure 1: Browser/server architecture.

server, thus forming a three-tier structure framework of the client, browser, and server. The evaluation system of this model can effectively reduce the development, maintenance, and upgrade costs of the evaluation system. It simplifies the operation process of the client and effectively improves the system's efficiency [15].

Adolescent social anxiety patients send a request to the web server through the browser. The browser displays the requested data of adolescent users, such as pictures or videos, while receiving the file [16]. After receiving the request, the server sends the request to the database server that stores the data for execution and returns the results from the database server to the system browser in the form of an HTML file [17].

3.2. Function and Structure Design of Cognitive Behavior Diagnosis and Treatment Evaluation System for Adolescents' Social Anxiety. The cognitive behavior diagnosis and treatment evaluation system of juvenile social anxiety includes three modules. They are evaluation, audit, and qualification modules. According to relevant doctors' actual positions and titles, correctly divide the roles of superior doctors and ordinary doctors, and set the operation authority for different roles. The operation authority of superior doctors is higher than ordinary doctors. It has the function of qualification review. Figure 2 shows the functional design of the module of the cognitive behavior diagnosis and evaluation system for adolescents' social anxiety.

The overall functional modules of the system are described in Figure 2.

3.2.1. Youth User Registration and Login. After registration, new users can only enter the cognitive behavior diagnosis and treatment evaluation system. Before dividing the operation authority of new users, they must submit their real information for qualification and authentication, and the superior doctor decides whether they are qualified to enter the evaluation page. It can effectively avoid malicious registration and chaotic management [18].

There are two ways for users to log in: user name login and mobile phone number login. After registration, users

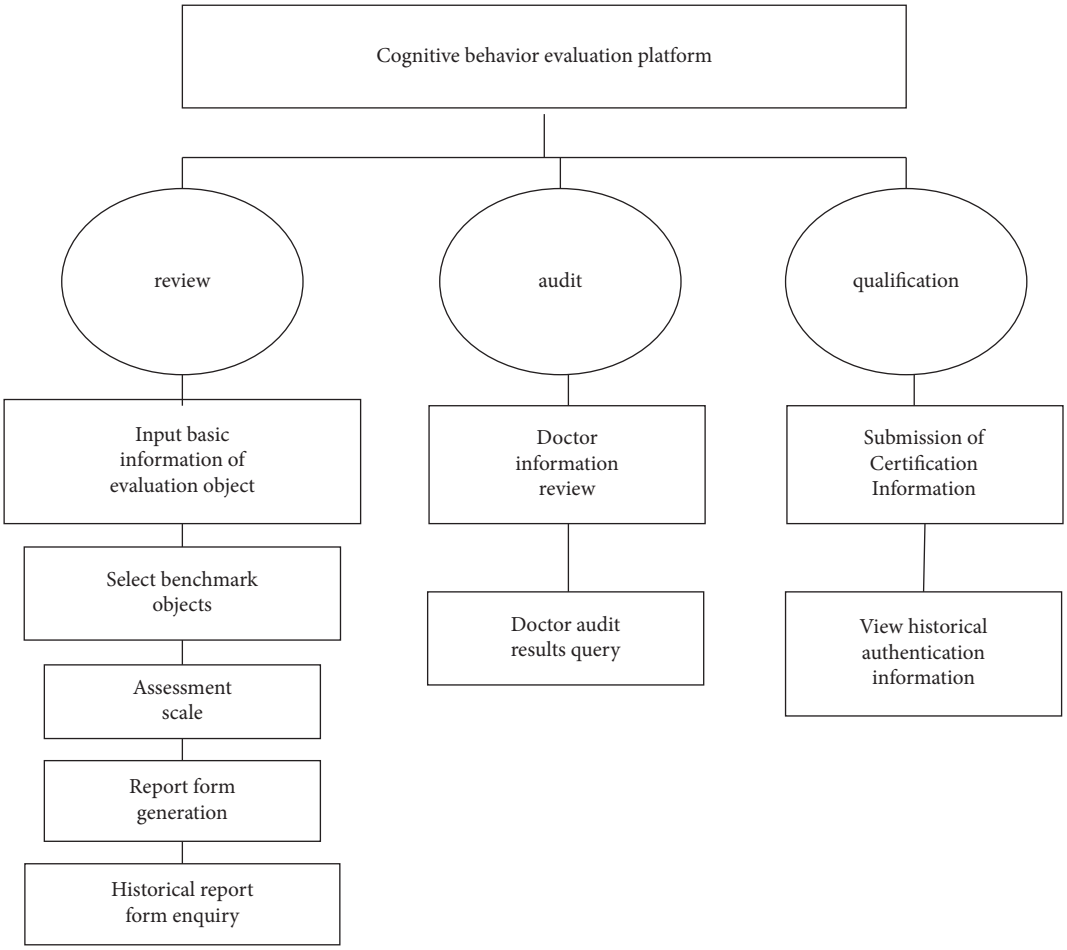

Figure 2: Functional design of main modules of the cognitive behavior evaluation platform.

must enter the correct user's name and password on the login page of the cloud platform to enter the diagnosis and treatment evaluation platform. It is convenient for users to log in to the system even if they forget their password [19].

3.2.2. User Evaluation Module. New users can conduct evaluation operations after completing the registration and review. Currently, users (doctors) registered on the evaluation platform can only conduct cognitive function evaluation on the evaluation object (adolescent social anxiety patients) entered into the account. Patient information and evaluation results cannot be shared among evaluation doctors. It can effectively avoid the disclosure of patient information.

3.2.3. User Audit Module. The qualification review function of the cognitive behavior evaluation platform for adolescent social anxiety can provide doctors with the ability to review the qualification information submitted by new users, reject or receive operations, and perform the cognitive behavior evaluation function only after reviewing new users. In addition, the qualification review page can also query and display the review status of subordinate users. After passing the audit, if the new user registers under the professional title, he/she will obtain the audit qualification. If not, he will be a general evaluation doctor. The superior doctor can choose to refuse or accept the operation.

3.2.4. User Qualification Authentication Module. The qualification certification of adolescent social anxiety cognitive behavior evaluation platform can carry out qualification certification for login users. The newly added users must fill in the certification and submit the certification [20]. They can only use the system evaluation function after being reviewed and confirmed by the superior doctor. If the review fails, the new user can continue to submit the qualification certification and view the user's historical certification information on the page.

3.2.5. Structure of Cognitive Behavior Evaluation System. The use process of the cognitive behavior evaluation platform is shown in Figure 3. It shows the current cognitive behavior evaluation platform for adolescent social anxiety. Doctors are only allowed to register and review the qualification of subordinate doctors or evaluate patients according to their needs. According to web page prompts, the above operations can be realized by logging in to relevant web pages through the browser.

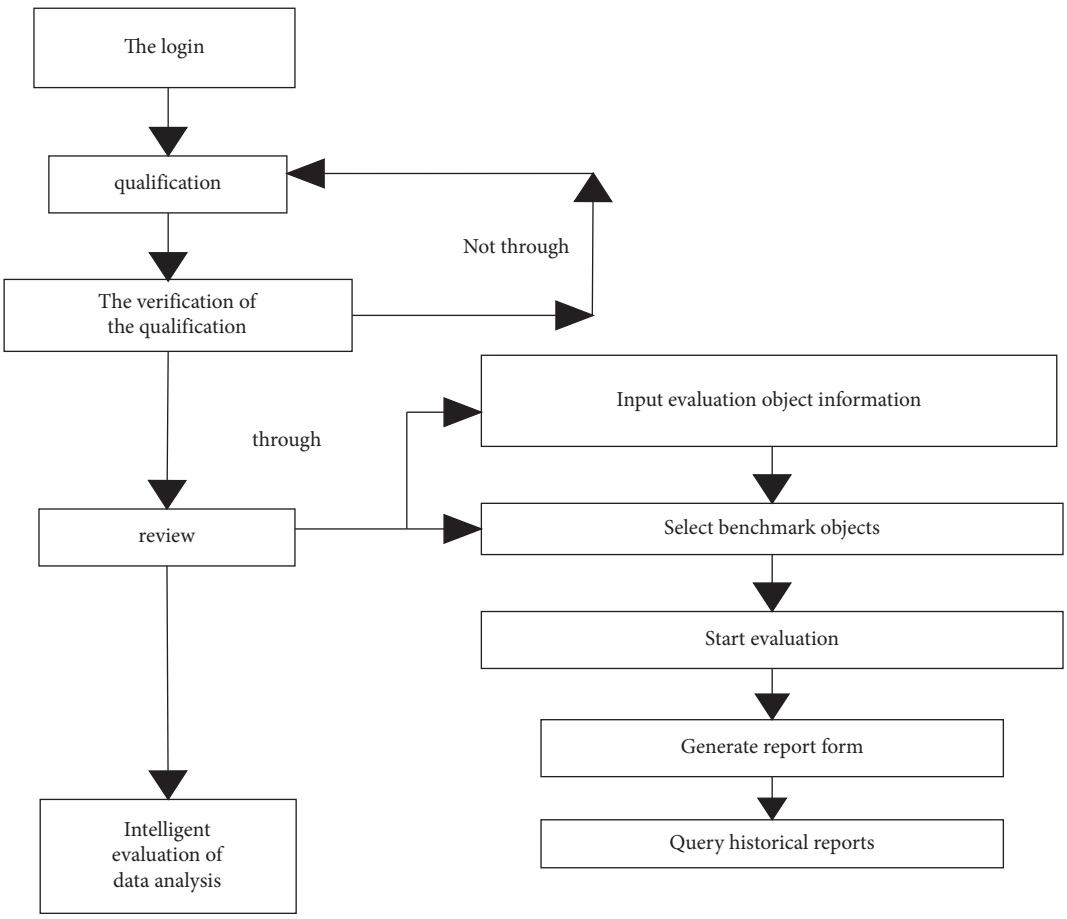

Figure 3: Flow chart of using cognitive behavior evaluation cloud platform.

3.3. Database Design. The database of adolescent social anxiety cognitive behavior evaluation system mainly refers to the abstraction of the analyzed information after analyzing the users' needs. It is used to obtain the system information world structure and implement the database. The database in the system contains many relational tables. This paper specifically represents the doctor's table and patient table.

3.3.1. Doctor Table. This table stores the basic information of login users (doctors). It includes the user ID, gender, and audit status. The basic information structure of doctors is represented in Table 1.

3.3.2. Basic Patient Information. This table stores all patient information entered by the current login user, including name, outpatient number, and address. The information table of adolescent social anxiety patients is represented in Table 2.

Table 1: Basic information of doctors of login users.

The data type	Primary key or not	The length of the	Null	The field
Bigint	Is	20	No	Id
Bigint	No	20	Is	The logged in user
Bigint	No	20	Is	Position
Bigint	No	20	Is	The title
Varchar	No	50	Is	The name
Tinyint	No	1	Is	Gender
Int	No	11	Is	Age
Bigint	No	20	Is	Audit doctor ID
Tinyint	No	1	Is	Review the status

4. Predictive Modeling of the Relationship between Cognitive-Behavioral Therapy and Adolescent Social Anxiety Based on Deep Learning

This section explains the characteristics of vector acquisition of adolescent social anxiety performance weight and the establishment of a correlation prediction model. Based on deep learning, it will help clarify the predictive modeling of the relationship between cognitive-behavioral therapy and adolescent social anxiety. The explanation is as follows.

4.1. Vector Acquisition of the Weight of Adolescent Social Anxiety Performance Characteristics. In the process of predicting and optimizing the correlation between cognitive-behavioral therapy and adolescent social anxiety, the risk and protective factors of adolescent growth are screened

Table 2: Basic information of patients.

The data type	Primary key or not	The length of the	Null	The field
Bigint	Is	20	No	Id
Bigint	No	20	Is	The logged in user
Varchar	No	50	Is	The name
Varchar	No	50	Is	Outpatient service no.
Varchar	No	50	Is	In the hospital
Varcher	No	50	Is	ID number
Tinyint	No	1	Is	Gender
Varcher	No	200	Is	Address
Varcher	No	500	Is	Note
Timestamp	Is	0	No	Creation time

from the perspectives of individuals, school, family, and society. The support degree of factor fuzzy itemset is defined. The vector of morphological feature index weight of adolescent social anxiety is calculated. The detailed steps are as follows.

Use (1) to obtain all the factors causing teenagers' social anxiety:

$$D = \frac{[Xy]_{N\times n+1}}{X}. \tag{1}$$

In (1), X represents the factors that cause teenagers' social maladjustment, y represents the social events that aggravate teenagers' social maladjustment, N represents the category attributes of different factors, and n represents the function of membership on attributes.

The factors causing adolescents' social anxiety mainly come from social stress, traumatic events, or the accumulation of individual environmental stress [13]. In the process of teenagers' growth, the factors that affect their growth are risk and protective factors. These two factors are two extremes of the same variables. Whether the variable is a certain factor depends on the score of the corresponding variable of the adolescent individual, not the attribute of the variable itself [14]. Therefore, the risk factors and protective factors in the growth process of teenagers are screened out from all factors in formula (1). It is assumed that $(Z_1, Z_2 \ldots Z_n)$ represents the different attributes of all factors causing teenagers' social anxiety. Formula (2) is used to calculate the value of Category attribute Z_{n+1} as

$$Z_X = \frac{(Z_{n+1}) \times D_k}{x_k \cdot [Z_1, Z_2 \ldots Z_n] \times D} \times A_i Z_{n+1}. \tag{2}$$

In formula (2), x_k represents the samples of different factors causing teenagers' social anxiety, (Z_{n+1}) represents the function of attribute Z membership, D_k represents the fuzzy membership value of attribute k of teenagers' social anxiety factors, and A_i represents the number of attribute k membership functions.

If D_f represents the sample of unknown factors of adolescent growth, r_j represents the fuzzy correlation between adolescent growth factors and family, school, and society and screens the risk factors and protective factors of adolescent growth according to the calculated Z_{n+1}.

$$Fu = \frac{r_j \times \mathrm{FS}(\langle Z\colon R\rangle) \cup (\langle Y\colon C\rangle)}{\mathrm{FS} \times D_f \times Z_X \times Z_{n+1}}. \tag{3}$$

In formula (3), FS represents the growth factors of teenagers and the fuzzy association rules between people, families, schools, and society. $\langle Z\colon R\rangle$ represents the growth factors of teenagers and the risk factors of people, families, schools, and society. $\langle Y\colon C\rangle$ represents the growth factors of teenagers and the protective factors of people, families, schools, and society.

Through formula (4), the fuzzy itemset support of risk factors and protective factors is defined and expressed as

$$\widehat{y_k} = \frac{\arg\max(v) \times q^l \times Fu}{\mathrm{FS}(\langle Z\colon R\rangle) \times (\langle Y\colon C\rangle)}. \tag{4}$$

In formula (4), $\max(v)$ represents the fuzzy frequent item sets of different factors, q represents the analogy setting of samples of different factors, and l represents a new index for evaluating the support of fuzzy item sets of different factors.

Here, S_B represents the manifestation of teenagers' social anxiety, S_A represents the manifestation of being at a loss, and S_Q represents the manifestation of rapid heartbeat. Substitute formula (4) into formula (5) to obtain the vector of characteristic index weight of adolescent social anxiety:

$$vc(r_j) = \frac{\sum v_p \cdot \widehat{y_k} \times f_1(S_A) \times (S_B) \times (S_Q)}{f_\Delta \times f_\xi \times f_\phi}. \tag{5}$$

In formula (5), v_p represents the distinction between the characteristic membership functions of the manifestations of adolescents' social anxiety, f_1 represents the number of characteristic variables of the manifestations of adolescents' social anxiety, f_Δ indicates the morphological characteristics of being at a loss, f_ξ indicates the characteristics of the manifestations of heartbeat acceleration, and f_ϕ indicates the manifestations of adolescents' cognitive behavior [17, 18].

4.2. Establishment of Correlation Prediction Model. On the basis of obtaining the weight vector of the morphological characteristics of adolescents' social anxiety, a correlation prediction model is established. The specific process is as follows.

$(Z_{ij})_{n\times m}$ represents the weight of different factors of teenagers' social anxiety and $(V)_{n\times m}$ represents the vector ranking the different factors of teenagers' social anxiety. Based on the above acquisition of $vc(r_j)$, the vector optimal value of the weight of the characteristic index of the expression form is defined. It is expressed as

$$X_\gamma = \frac{(Z_{ij})_{n\times m} \times vc(r_j)}{r_1 \times f_{i\times\eta} \times f_m \cdot f_n} \times W_{m1}. \tag{6}$$

In formula (6), W_{m1} represents the incommensurability between different factors, r_1 represents the number of

factors, f_m represents the subjective factors of teenagers' social anxiety, f_n represents the objective factors of teenagers' social anxiety, η represents the deviation of different factors, and $f_{i\times\eta}$ represents the proportion of different factors of teenagers' social anxiety and meets the condition of $\eta \leq 0$.

The correlation prediction model between cognitive behavior and adolescent social anxiety is established through

$$vc(\mathrm{RT}) = X_\gamma \times W_{m1} \frac{H(Y)}{f_{i\times\eta} \times (Z_{ij})_{n\times m}} \cdot \psi. \quad (7)$$

In formula (7), ψ represents the judgment matrix of adolescents' social anxiety. The above process completes the prediction research on the diagnosis and treatment effect of adolescents' social anxiety based on deep learning cognitive-behavioral therapy.

5. Analysis of Experimental Results

In order to verify the effectiveness of cognitive-behavioral therapy based on deep learning in predicting the diagnosis and treatment effect of adolescent social anxiety, simulation experiments were carried out. 100 adolescents with social anxiety were selected for experimental data with an average age of 16 years. The system requirements for experimental data and simulation are shown in Table 3.

Table 4 shows the prediction time comparison between the relevance prediction model of adolescents' social anxiety and the traditional relevance prediction model of cognitive-behavioral therapy based on deep learning proposed in this paper.

The analysis of Table 4 shows that the prediction time of the correlation prediction model proposed in this paper is different from the traditional correlation prediction model. The prediction time of the model proposed in this paper is significantly faster than the traditional method. Figure 4 shows the accuracy comparison between the correlation prediction model and the traditional model proposed in this paper. It shows that the relevance prediction model proposed in this paper can effectively improve teenagers' social anxiety prediction efficiency.

As shown in Figure 4, the accuracy of the traditional prediction model in predicting the diagnosis and treatment effect of adolescent social anxiety is not high since the experiment. With the number of experiments, the overall accuracy has not been significantly improved. The prediction accuracy of the correlation prediction model used in this paper is higher from the beginning of the experiment. The overall accuracy has been very stable with the increasing number of experiments. Figure 5 shows the stability comparison between the proposed correlation prediction model and the traditional model proposed in this paper. It shows that the relevance prediction model proposed in this paper can well predict adolescent social anxiety's diagnosis and treatment effect.

The method proposed in this paper has good overall stability at the beginning and end of the experiment. As shown in Figure 5, when the traditional prediction model predicts the diagnosis and treatment effect of adolescent social anxiety, the stability of the model is 71% at the beginning of the experiment. It gradually decreases with the increase in the number of experiments. Figure 6 shows the complex comparison between the proposed correlation prediction model and the traditional model proposed in this paper.

The analysis of Figure 6 shows that the complexity of this model in predicting the correlation between cognitive behavior therapy and adolescent social anxiety is significantly lower than that of the traditional model. It shows that the overall process of this model in predicting the correlation between cognitive behavior therapy and adolescent social anxiety is relatively simple and feasible. Figure 7 shows the correlation prediction model proposed in this paper and the

Table 3: System requirements.

System requirements	Recommended
The operating system	Windows 10
The processor	Intel(R)Xeon(R)
Run a memory	128 GB
The simulation environment	MATLAB

Table 4: Comparison of prediction time of different prediction models.

Methods	Time (s)
Methods followed in this paper	25
From traditional method	57

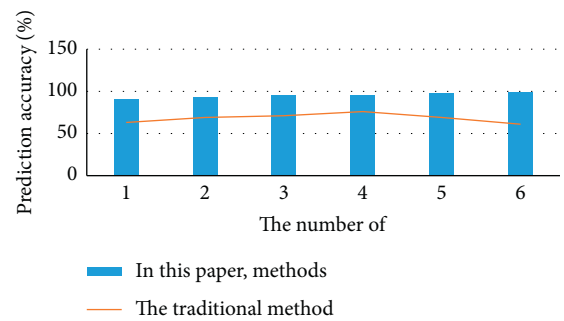

Figure 4: Comparison of accuracy of different prediction models.

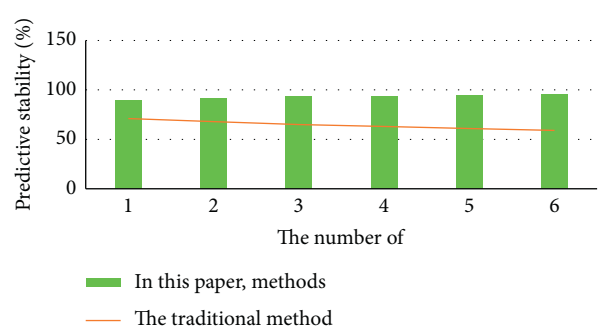

Figure 5: Stability comparison of different prediction models.

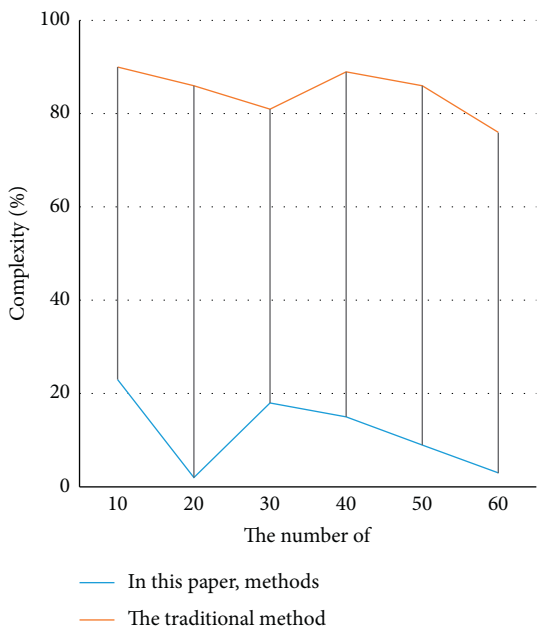

Figure 6: Complexity comparison of different prediction models.

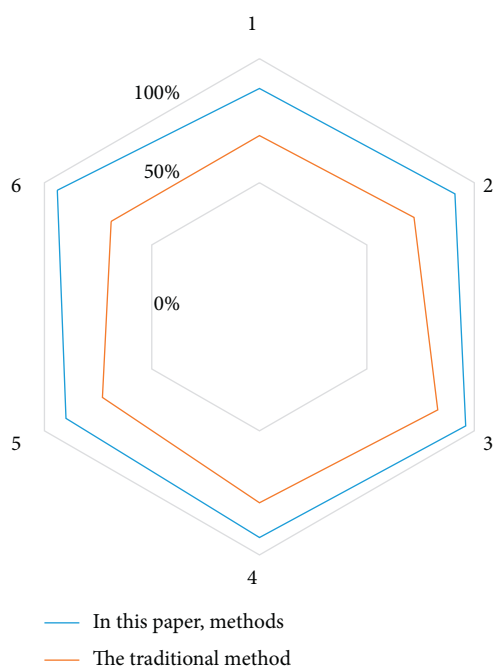

Figure 7: Effect of different models for alleviation of adolescent social anxiety.

effect comparison between the traditional model. The traditional model is applied to diagnosing and treating adolescent social anxiety.

Through the analysis of Figure 7, it can be seen that the effect of applying the traditional model to the diagnosis and treatment of adolescent social anxiety is poor. The cognitive behavior therapy based on deep learning proposed in this paper has a good effect on diagnosing and treating adolescent social anxiety. Therefore, because this paper constructs the correlation prediction model between cognitive behavior therapy and adolescent social anxiety and treats adolescent social anxiety through cognitive behavior therapy, it can effectively alleviate adolescent social anxiety.

6. Conclusion

To effectively alleviate the current social anxiety of adolescents, the effect prediction of cognitive behavior therapy based on deep learning applied to the diagnosis and treatment of adolescent social anxiety was studied. Firstly, the system of adolescent social anxiety is constructed. Secondly, the correlation prediction model between cognitive behavior therapy and adolescent social anxiety based on a multi-objective evolutionary algorithm is constructed. Anxiety disorders appear to be stealthy, with a protracted clinical course, low recovery rates, and high recurrence rates, according to these studies. The existence of particular concomitant mental conditions reduced the chances of recovery and increased the likelihood of recurrence of anxiety disorders. The risk and protective factors in the growth of teenagers are screened from the perspectives of people, family, school, and society. The subjective and objective factors of teenagers' social anxiety are extracted utilizing the grey correlation degree. Similarly, the correlation prediction model between accurate cognitive behavior therapy and teenagers' social anxiety is also established. Compared with other models, the method proposed in this paper can effectively improve teenagers' social ability and is feasible. The findings contribute to our knowledge of the illnesses' nosology and management.

Data Availability

All the data are included within the article.

Conflicts of Interest

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

Acknowledgments

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Research Article

Digital Transformation Path for Manufacturing Enterprises Using Internet of Things and Data Encryption Technology

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Innovation in products or services is crucial for industrial manufacturing businesses in countries that prioritize exports. A plethora of advancements based on the internet of things (IoT) applications has been made possible by the falling prices of processing power, communication, and electrical components. Only a small number of industrial manufacturing enterprise-specific IoT applications have been effective yet. The present literature does not fully explain this scenario, which is very necessary for taking the advantage of IoT in manufacturing enterprises. In order to adapt to the change in digital market demand and enhance the market competitiveness of manufacturing enterprises, this paper aims to study the digital transformation path of manufacturing enterprises based on the internet of things (IoT) and data encryption technology. A digital transformation service system is built for manufacturing enterprises based on the IoT and data encryption technology to help manufacturing enterprises fully understand their own digital degree, provide effective suggestions for the digital transformation, and introduce the overall architecture and functional structure of the service system in detail. A distributed intelligent recommendation method is proposed that is based on personalized customization and recommends transformation schemes for businesses in order to better direct users' product customization and decision-making and allow the users to accurately describe their own needs, improve customization efficiency, introduce intelligent recommendation methods, and strengthen the basis of collaborative filtering methods based on items. The simulation result demonstrates that the service system proposed in this study performed really well in terms of both accuracy and time consumption. It is anticipated that the suggested approach will successfully raise the digital maturity of manufacturing companies and will help them in increasing their ability to compete in the current market.

1. Introduction

The manufacturing industry is the pillar industry of a country, which directly reflects the overall production level of a country. With the gradual convergence of industrialization and information technology (IT), a new strategic direction is brought for the rapid development of the manufacturing industry. In the current era of digitization, IoT and big data technologies have been gradually applied to various manufacturing industries. As a result, personalization and the change in digital product and service modes have been initiated. The drive mode of some traditional elements, such as capital investment will inevitably be replaced by the digitized innovation-driven development mode. Digitizing can drive productivity and production relationships. Digitization is the dynamic basis and source of energy for the transformation of manufacturing enterprises. Research on the transformation path of digitization of manufacturing enterprises has become the focus of current problem-solving techniques. Digitization transformation mainly takes digital industry and industrial digitization as the direction of the development of manufacturing enterprises. Enterprise integration and enterprise digital platform are built as the supporting mechanism inside and outside enterprises, which can better adapt to the changes in digital market demand.

IoT is an infrastructure that embeds electronics, circuitry, software, sensors, and network connectivity into physical objects including machines, instruments, buildings, cars, and other things for the purpose of data collection and sharing. Through the use of the current network infrastructure, IoT enables us to detect and control things

remotely. This allows for a closer connection between the real world and computer-based systems, which boosts efficiency and accuracy [1]. IoT opens a door not only for smart homes but also for the smart industry where things are either entirely or partially managed by machines. Production sites and factories are two examples of the primary categories of smart industry. The first one is the setting for discrete manufacturing, while the second one is technologically specialized production. The use of IoT on "production sites" to improve operations and fine-tune processes would minimize losses from the ineffectiveness of the decisions taken by 5–12.5%. In addition, to enable continuous production process monitoring, IoT deployment in factories also facilitates better inventory management [2].

Under the background of the rapid development of IT, every country has put forward a transformation strategy for manufacturing enterprises. Accelerating the integration of industrialization and IT as well as digitizing the transformation of manufacturing companies are crucial for China to become a powerful manufacturing nation. However, currently, manufacturing enterprises are not fully utilizing the potential of IT. Therefore, it is very crucial to pay attention to the fact that how to digitally transform industrial businesses on the basis of IT development. For this reason, the digitized transformation path of manufacturing enterprises based on the IoT and digital encryption technology is deeply studied so that manufacturing enterprise can improve their digitization level and realize the practical value of digitized transformation of manufacturing enterprises on the basis of their own development.

The innovations of this paper are as follows: (1) firstly, a digital transformation service system for manufacturing enterprises based on the IoT and data encryption technology is built, and the overall structure and functional structure of the service system are described in detail. (2) Secondly, a distributed intelligent recommendation method based on customization is proposed, and the specific path of digitized transformation of manufacturing enterprises is analyzed. (3) Compared with other research methods, the overall performance of the service system proposed in this paper is better, and the methods can effectively improve the digitization level of manufacturing enterprises, thereby enhancing the market competitiveness of enterprises.

The rest of the paper is organized as follows: Section 2 discusses the work done in the literature on the digital transformation of manufacturing enterprises. Section 3 is about the digital transformation service system for manufacturing enterprises based on IoT and data encryption technology. This section further discusses the overall architecture of the digital transformation service system for manufacturing enterprises and the system's functional architecture. Section 4 describes the distributed intelligent recommendation algorithm based on personalized customization by explaining the computing similarity of attribute values of articles in manufacturing enterprises, measuring the interests and interests of target users in manufacturing enterprises, and auxiliary customization to generate recommended results. Section 5 sheds light on the result of the experiment conducted in the study. Section 6 finally concludes the overall theme of the paper.

2. Related Work

In terms of the research on business transformation and the theory of digital transformation, certain developed nations are relatively young. These nations serve as a source of inspiration for the study of the digital transformation route taken by manufacturing firms in China. In view of the opportunities and challenges that the digital economy brings to the development of enterprises, especially, the digital transformation of manufacturing enterprises in China has important practical significance. With some manufacturing enterprises as the object of study, based on some theories such as path dependence on the technological trajectory, this paper uses the fuzzy set comparative analysis method to discuss the effect mechanism of some factors such as the property rights of enterprises, the size of enterprises, and the years of establishment on the selection of the digitized transformation path of enterprises. The results show that enterprise scale is the core condition in the enterprise transformation path before, during, and after the process. Small-scale businesses with medium or low technological development will pick the digital transformation, the nature of the property rights, the enterprise scale, and the inventive environment to be replaced during the process of digitization. Manufacturing enterprises with low and medium technological development tend to select the transformation path of product service types. The analysis conclusion shows that it can provide practical guidance for manufacturing enterprises to achieve digital transformation, but it does not improve the overall strength of enterprises [3]. Shi et al. [4] claim that as the world has progressed into the digital age, the relationship between manufacturing and digital technology is increasingly closing. The digital transformation of manufacturing companies is a crucial necessity to effectively improve the core competitiveness of organizations and achieve rapid development given the shift in technology innovation, production demand inside the firm, and external environmental variables. According to the author's claim, his proposed study examines the digitization level status of manufacturing enterprises in a region using sample data analysis of more than 100 manufacturing enterprises on the integration platform of digitization. It also evaluates the level of digitization of manufacturing enterprises comprehensively from the dimensions of the enterprise's infrastructure, product life cycle, and production management control and highlights the weak links in the process of digitization transformation of manufacturing enterprises. Effectively promote the integration of digital technology and manufacturing enterprises to provide data support, but this method does not reduce the production costs of enterprises. In conjunction with the acceleration of manufacturing digitization in recent years, Wang et al. [5] highlight some issues existing in the daily operation of traditional manufacturing enterprises, such as the lack of automation in settlement and the low transparency of business data, which cannot be trusted as evidence. Blockchain technology has the

characteristics of transparency and trustworthiness, and combined with IoT technology, it can help manufacturing enterprises take targeted solutions to the problems in the digital transformation. To this end, the matching system of service automation in manufacturing enterprises is designed based on the ant colony algorithm to provide tracking services using blockchain and the IoT. The simulation results show that the enterprise digital transformation scheme is feasible that can effectively reduce the cost of enterprise operation and settlement and can effectively enhance the transparency and reliability of enterprise business information. However, it does not improve the overall competitiveness of manufacturing enterprises. According to Zheng et al. [6], the digitized transformation opens up opportunities for the economic development of manufacturing enterprises and has a significant impact on that development. This is because the current market economy has gradually transitioned into the era of the digitized economy. The state proposes corresponding policies, takes standardization as the background, employs the hierarchical analysis method, and starts with the development status of manufacturing enterprises. It then conducts an extensive analysis of the influencing factors of digitized transformation of manufacturing enterprises, combines it with reality, and proposes the counter-matter. Finally, from the perspective of high-quality development goals for manufacturing enterprises [7], it is suggested to work together from many aspects, such as standardization methods, enterprises themselves, and consumer theory, to effectively achieve the digital transformation of manufacturing enterprises; however, this method does not improve the overall competitiveness of enterprises themselves.

3. Digital Transformation Service System for Manufacturing Enterprises Based on IoT and Data Encryption Technology

This system is for manufacturing enterprises that need digitizing transformation. Its primary goals are to fully assist manufacturing companies in understanding their degree of digitization, to offer practical suggestions for their digitization transformation, to assess their level of digitization, to clearly understand their issues and gaps, and to assist the government, businesses, and industrial organization systems in promoting digitization work [8, 9]. In order to provide scientific decision-making basis for manufacturing enterprises, this system not only needs to have an information display function but also needs to provide an evaluation diagnostic model to support automated diagnosis and expert evaluation diagnostic function. The specific business architecture of the proposed system is illustrated in Figure 1.

In Figure 1, the system divides users into visitors as well as demanders, service providers, diagnostics experts, and platform administrators. Visitors who are not registered on the system can only browse the system display. Manufacturing enterprises need to authenticate after they register on the system. Demanders can publish their own requirements and view solutions; service providers can publish solutions and view the needs of demanders; and platforms provide docking capabilities [10, 11]. Experts are assigned by system administrators and are specifically responsible for docking manufacturing enterprise consultation and customized diagnostics. Administrators are primarily responsible for system security and portal information content maintenance, as well as diagnostic evaluation of the creation and maintenance of diagnostic templates in subsystems.

3.1. Overall Architecture of Digital Transformation Service System for Manufacturing Enterprises. The system is being developed using a front- and back-end split architecture mode, which is a novel architectural method for IoT application development. Traditional and most of the existing Web development is based on the model view controller (MVC) model. During the process of development, the front-end pages of the system are prone to generate a large amount of back-end code. As a result, the front-end development of the system will rely heavily on the back-end, which is not conducive to the later debugging and maintenance of the system, resulting in some problems such as low development efficiency and high maintenance costs [12, 13]. When the front end and back end of a system are operated separately, the front end only concentrates on the impact and user experience of the system pages. The back-end of the system no longer focuses only on the page display of the front-end of the system but also on the issues of high performance and high concurrency. The front end and back end of the system make use of the RESTful style API interface, which is the interface communication for transferring JSON data API. The front end and back end of the system are independent projects, and different servers are deployed, which improves the overall performance of the system and the user experience. The technical framework of a digitized transformation system in a manufacturing enterprise is represented in Figure 2.

In Figure 2, the front end of the digital transformation service system in manufacturing enterprises is the Vue framework, which is a progressive framework for building the user interface, can be applied from the bottom to the top, and has rich class library support. The data access layer (DAL) uses a JPA framework, provides a simple programming model, supports advanced object-oriented features, supports container-level transactions such as large datasets and concurrency, and simplifies the code for the DAL [14, 15].

3.2. System Functional Architecture. The main purpose of the digital transformation service system development is to provide specialized services for the digital transformation of manufacturing enterprises, including diagnostic evaluation, transformation solutions, and other functions. Based on the business process of Figure 1, the modular design of system functions is carried out, and the system function block diagram is provided as shown in Figure 3. According to different user roles, the system is divided into three

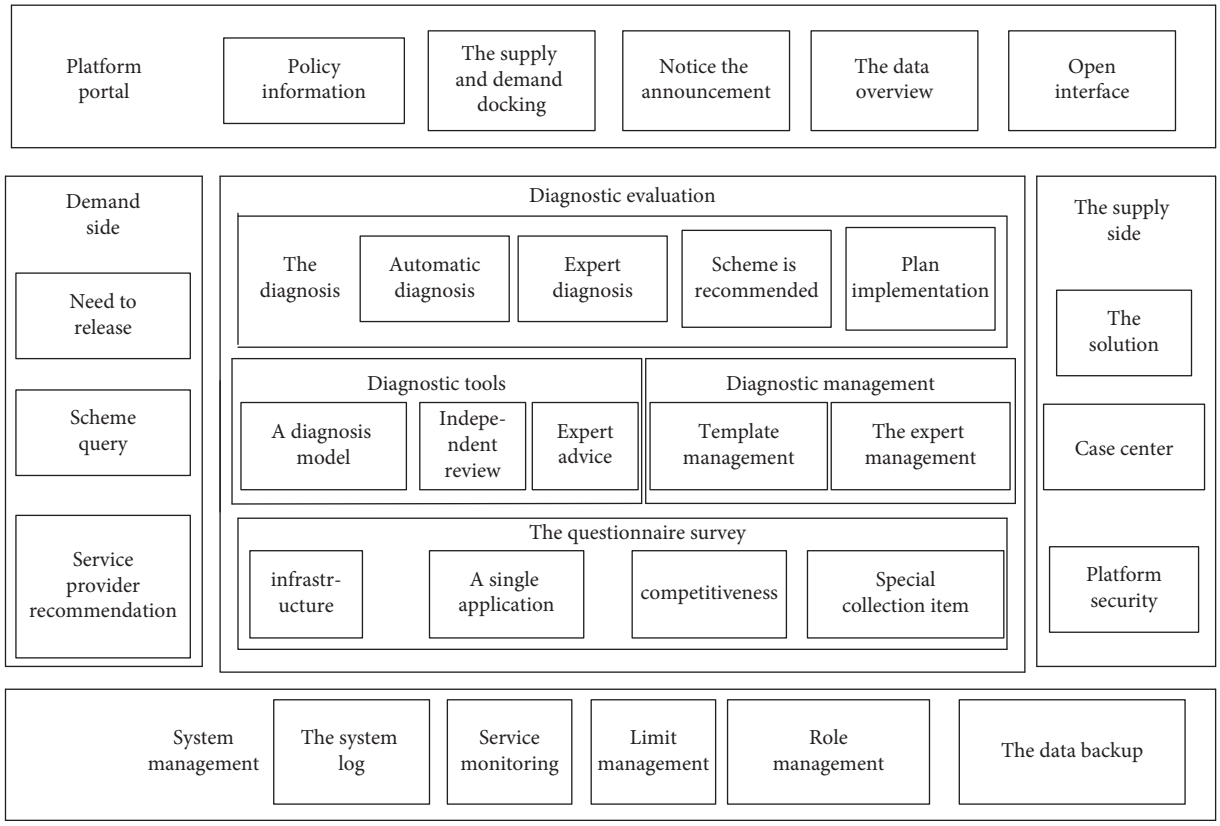

Figure 1: Specific business architecture of the system.

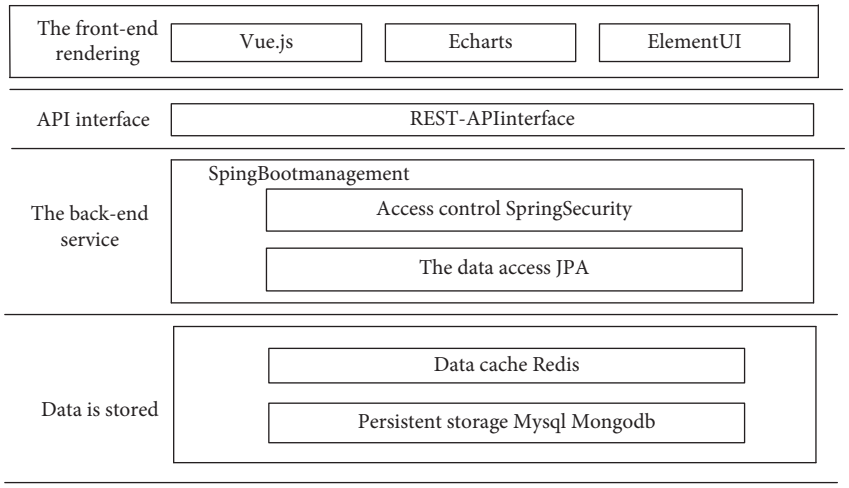

Figure 2: Technical architecture of digital transformation system for manufacturing enterprises.

subsystems: portal system, enterprise management system, and background management system [16, 17].

In Figure 3, (1) the portal system is mainly open to all users and is the entry point for the digital transformation service system of manufacturing enterprises. Users can browse the latest policy information, industry trends, national enterprise digitization development, and enterprise publishing requirements and provide users with relevant content and information about digital transformation. (2) Enterprise management system is for certified manufacturing enterprises, providing the docking of supply and demand, diagnostic evaluation, and expert consultation functions for suppliers and service providers. In this system, the demander may post the enterprise's own needs; the service provider can submit answers; and once the requirements or solutions are posted, and all users can access them in the portal system [18, 19]. Provide functional support for manufacturing enterprises in the diagnostic evaluation module. After a manufacturing enterprise has been certified, the digitization level of its own

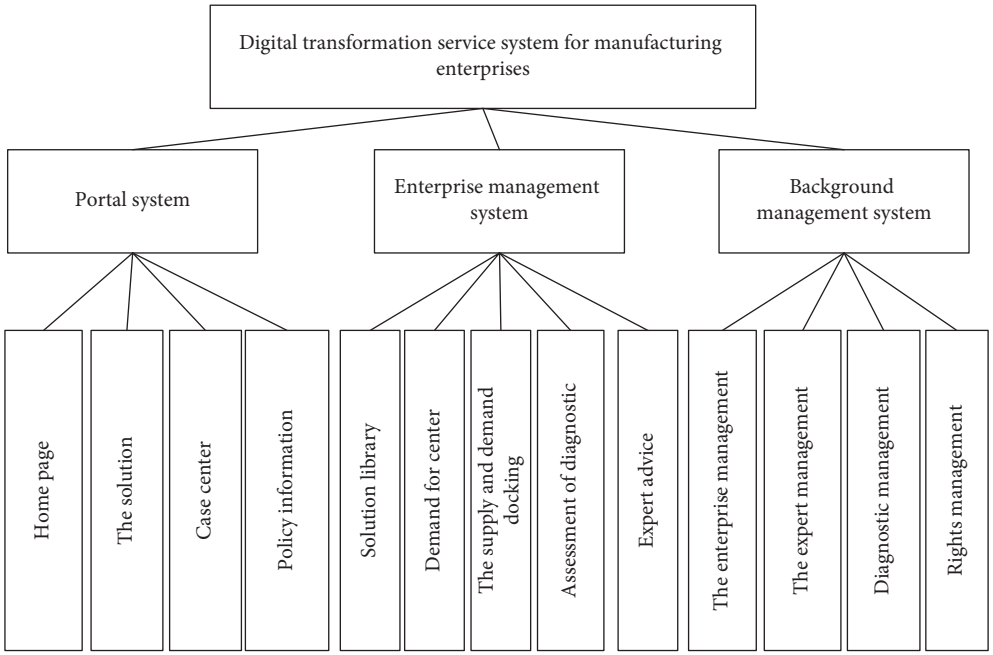

Figure 3: System function block diagram.

enterprise can be understood by filling in the system questionnaire, obtaining digitized transformation path suggestions and recommended solutions, and contacting experts to provide customized diagnostic consulting services. (3) Background management system is mainly open to administrators and experts. The functions of administrators include diagnosis management, template management, expert management, news dynamic management, and right management. System administrators can use the background system to develop configuration templates and questionnaires, assign expert accounts, manage registered enterprises, and so on. A diagnostic expert consists of a review of the diagnostic process and an expert response. Experts can review the status of questions and answers issued by manufacturing enterprises in the system, reply to enterprise customized consultations, and upload corresponding reports of customized evaluation.

4. Distributed Intelligent Recommendation Algorithm Based on Personalized Customization

Personalized customization is the main way of digitized transformation of manufacturing enterprises. It is combined with the above-digitized transformation service system of manufacturing enterprises based on IoT and data encryption technology.

4.1. Computing Similarity of Attribute Values of Articles in Manufacturing Enterprises. Users- and item-based collaborative filtering algorithms are the two categories of collaborative filtering algorithms. An article-based collaborative filtering algorithm is chosen as the foundational method in this study before the enhancement. The similarity between two items is defined by the following formula based on item collaborative filtering:

$$w_{ij} = \frac{|N(i) \cap N(j)|}{|N(i)|}, \tag{1}$$

where $|N(i)|$ represents the number of users who like the i-item, while $|N(i) \cap N(j)|$ represents the number of users who like not only the i item but also the j item. However, this calculation method will produce j items that are popular and may be liked by almost all users, so w_{ij} will approach 1 to some extent, but it cannot accurately reflect the strong similarity between item i and item j. For this reason, formula (1) is adjusted to reduce the weight of j items and prevent the most popular goods from being recommended:

$$w_{ij} = \frac{|N(i) \cap N(j)|}{\sqrt{|N(i)||N(j)|}}. \tag{2}$$

In distributed intelligent recommendation algorithms, although the recommendation object becomes an attribute value of a manufacturer's product, the recommendation principle is the same.

In order to reduce the sparsity of enterprise data and facilitate the production of manufacturing enterprises, the properties of product configuration content are considered in the recommendation, and the configuration scheme of user products is decomposed into a set of attribute values [20, 21]. Assuming A_i represents an attribute that needs to be customized, in establishing an enterprise product customization, it is possible to specify the number of characteristics a product consists of and their set value range. The a_{ij} is utilized to describe the attribute value of the jth type of the ith custom attribute, and there are also differences in the range of values for different i and j.

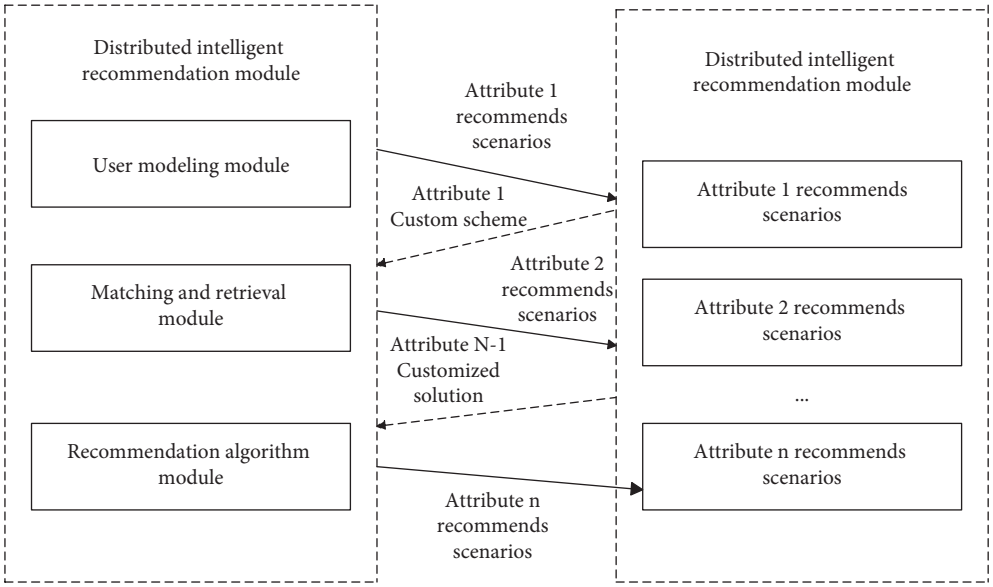

Figure 4: Step-by-step intelligent recommendation process.

Table 1: Experimental configuration table.

Environmental parameters	Server	General computer
CPU	Intel 4 Nuclear	AMD 4 core
RAM	64 GB	8 GB
Hard disk	1 TB SDD	500 GB machinery
Operating system	Windows	Linux
Database	MySQL	MySQL

4.2. Measuring the Interests of Target Users in Manufacturing Enterprises. Considering how closely related the gathered attribute values are, the product attribute values of interest to the target users of the manufacturing enterprise are measured. In the article collaborative filtering algorithm, the interest of the enterprise target user u in the item j is calculated by using the following formula:

$$P_{uj} = \sum_{i \in N(u) \cap S(j,K)} w_{ji} r_{ui}. \tag{3}$$

Equation (3) is also applied to the proposed distributed intelligent recommendation algorithms. Among them, $S(j,K)$ represents a set of K attribute values with high similarity to enterprise product attribute value j; $N(u)$ represents a set of attribute values customized or interesting by manufacturing enterprise user u; w_{ji} represents the similarity between attribute value j and i that can be calculated based on the similarity matrix between attribute values; and r_{ui} represents the degree of interest of the user u in item i. For data sets with implicit feedback, when the user u behaves accordingly with an item i, then $r_{ui} = 1$.

4.3. Auxiliary Customization to Generate Recommended Results. Following the calculation of the user's interest in the attribute values of the present attributes, the first N attribute values of interest are recommended based on the user's level

Table 2: Comparison of recommended accuracy of different methods.

Number	Proposed method (%)	Methods of reference [5] (%)	Methods of reference [6] (%)
1	93	83	73
2	92	81	64
3	95	85	69
4	97	86	74
5	94	87	77

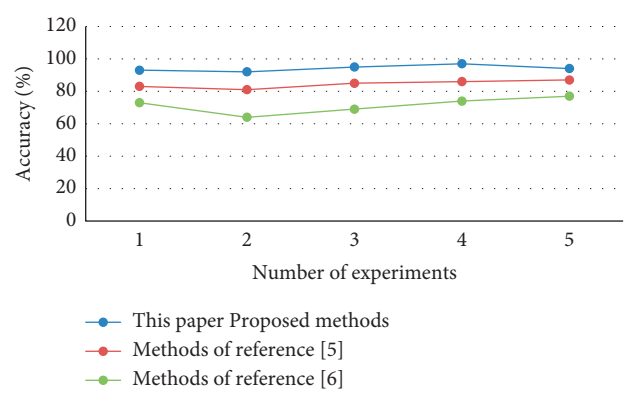

Figure 5: Reliability comparison of different recommended methods.

Table 3: Comparison of the recommended time for different methods.

Number	Proposed method (s)	Methods of reference [5] (s)	Methods of reference [6] (s)
1	12	23	31
2	15	25	42
3	16	28	38
4	13	29	49
5	17	26	45

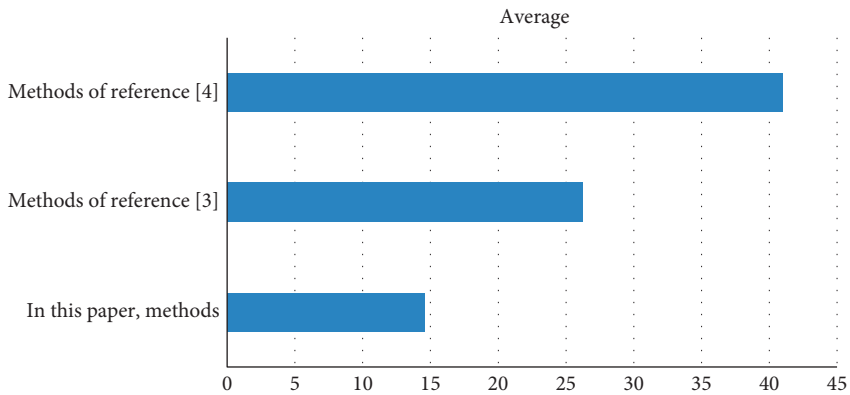

Figure 6: Average time taken by different methods.

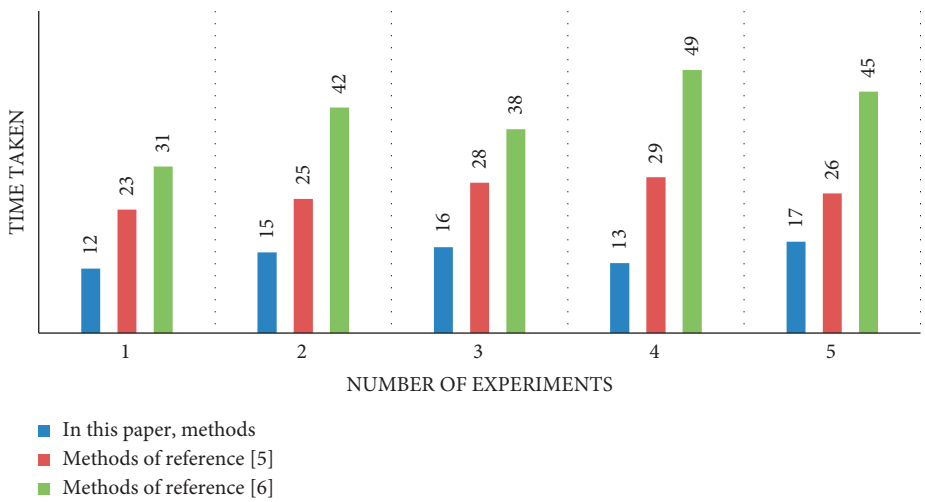

Figure 7: Time taken by different methods in recommendation.

of interest in various attribute values P. Measuring the similarity and distribution of item attribute values, enterprises can calculate the distribution of target users interest in attribute values to form a complete intelligent recommendation outcome, which is a custom solution set D_n. This scenario set is specifically formed by the combination of different attribute customization results. On the basis of receiving each recommended result, the user completes attribute customization [22, 23]. Figure 4 shows the specific flow of the distributed intelligent recommendation algorithm. Based on the recommendation results, the digitized transformation path of manufacturing enterprises based on the IoT and data encryption technology is completed.

5. Experimental Result

In order to prove the validity of the research on the digital path of manufacturing enterprises based on IoT and data encryption technology, this paper conducts simulation experiments. This experimental platform contains five nodes, one server, and four general computers. Table 1 is the experimental configuration table.

The accuracy of recommendation based on distributed intelligent recommendation algorithm proposed in this paper is compared with that in references [5, 6] through five experiments, which is represented by Table 2.

From the analysis of Table 2, we can see that the overall recommendation accuracy of the methods mentioned in [5] has a small fluctuation and has been stable between 80% and 90%. The overall recommendation accuracy is higher. The overall recommendation accuracy of the methods mentioned in [6] has a large fluctuation, but at the highest time, it has not exceeded 80%. In the five experiments, the methods mentioned in this paper have been kept above 90% because distributed intelligent recommendation is used. Produce products based on attribute values of interest to users, thereby enhancing the overall competitiveness of the enterprise and enabling the manufacturing enterprise to complete the digital transformation. Figure 5 shows the method presented in this paper and the reliability comparison of the methods in [5, 6].

Analysis of Figure 5 shows that the recommendation reliability based on distributed intelligent recommendation algorithm proposed in this paper has been stable at over 90% when recommending product attributes, reaching 98% in the fifth experiment. Although the reliability of the method proposed in the literature [5] may reach 80% in the first experiment, the reliability of the recommendation gradually

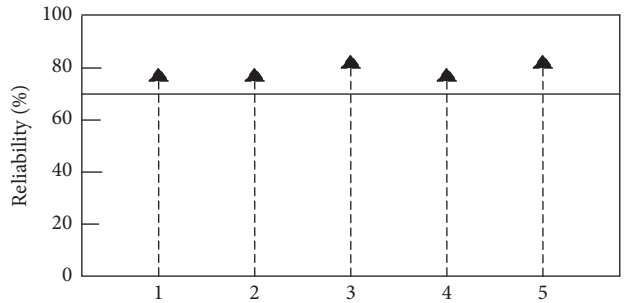

Figure 8: Overall performance of the system presented in this paper.

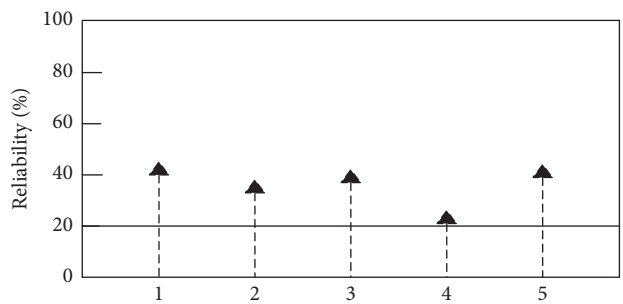

Figure 9: Overall performance of traditional system.

decreases with the increase of the number of experiments. Although the overall stability of the method proposed in the literature [6] is good, the reliability of the recommendation is only 40%, which shows that the method mentioned in this paper can ensure the reliability of the product attributes recommendation of manufacturing enterprises. Table 3 shows the method proposed in this paper and the recommended time comparison between the methods in [5, 6].

As can be seen from Figure 6, in the five experiments, the average recommendation time of the methods proposed in this paper is 14.6 s; the average recommendation time of the methods mentioned in [5] is 26.2 s; and the average recommendation time of the methods mentioned in [6] is 41 s. It is concluded that the proposed methods can effectively improve the efficiency of product recommendation, thus speeding up the transformation of manufacturing enterprises to digital as shown in Figure 7.

Figures 8 and 9 show the overall performance comparison between the digital transformation service system and the traditional system for manufacturing enterprises with the internet of things and data encryption technologies mentioned in this paper.

From the comparison of Figures 8 and 9, it can be seen that in several experiments, the overall performance of the traditional digital transformation service system of manufacturing enterprises is not up to 50%. However, the overall performance of the digital transformation service system of manufacturing enterprises based on IoT and data encryption technology mentioned in this paper is significantly better, which is above 70%. This is due to the employment of data encryption technologies and the IoT. An important way to effectively enhance the competitiveness of the manufacturing enterprise market and achieve high-quality development.

6. Conclusion

With the gradual advancement and integration of informatization and industrialization, digital transformation has become the key strategy of manufacturing enterprises in each country. Chinese manufacturing companies are concentrating their efforts on figuring out how to become digital under the presumption of their own development. Digital transformation is a long-term development process, and it is impossible to succeed in one go. At present, manufacturing enterprises are in an environment of high-speed development of IT. The level of an enterprise's own IT is especially important for the development of digitized transformation. Studying the digitized transformation path of manufacturing enterprises based on the IoT and data encryption technology is of great significance to the successful progress of the digitized transformation of manufacturing enterprises on the basis of the development of information technology. Therefore, in this study, a digital transformation service system for manufacturing enterprises based on IoT and data encryption technology is built, and the overall structure and functional structure of the service system are described in detail. Apart from this, we also proposed a distributed intelligent recommendation method based on customization and analyzed the specific path of digitized transformation of manufacturing enterprises. Our proposed method is of great significance as its overall accuracy is greater compared to the

existing methods. In addition, the average recommendation time of the proposed system is also the lowest among the present approaches, which shows the significance of the proposed system.

Data Availability

All the data are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Influence of Intelligent Internet of Things Technology on Taekwondo Athletes' Competitive Ability

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To maintain an advantage in the development of competitive sports, a country should explore the gap between Taekwondo athletes and other elite athletes. By comparing and analyzing to find out the reasons, it can create favorable conditions for the project and strive for greater advantages, which is the top priority for the project to develop. The purpose of this paper is to use the intelligent Internet of Things technology to analyze the factors affecting the competitive ability of Taekwondo athletes. Aiming at the competitive ability of Taekwondo, it analyzes the three aspects of psychological ability, technical ability, and tactical ability to construct a model of Taekwondo athletes' competitive ability. And for the indicators in the model, the intelligent Internet of Things technology is used to detect them in real time to achieve the best model construction effect. The experiment of this paper found that the competitive ability model of Taekwondo athletes' combining psychological ability, technical ability, and tactical ability is relatively successful. The Taekwondo competitive ability of athletes based on model analysis is almost the same as the competitive ability scored by experts, and the error is within 5%. It shows that psychological ability, tactical ability, and technical ability have important influence on the competitive ability of Taekwondo.

1. Introduction

In recent years, due to the adjustment of the Taekwondo arena and the revision of the competition rules, competitive competitions have begun to encourage athletes to attack. Particularly in the revision of the rules in 2017, the change of directly adding points to the opponent made the athletes pay more attention to the timing of the attack, which also puts forward higher requirements for the competitive ability of the world's outstanding taekwondo athletes. In competitive taekwondo competition, using reasonable techniques to attack is an important way to get the score. Only on the basis of mastering various techniques and tactics can athletes conduct effective attacks and win the game. Moreover, by analyzing the influencing factors of competitive ability, it is possible to improve or train the places with greater influence in a targeted manner, which can effectively improve the competitive level. Therefore, it is particularly necessary to analyze the influencing factors of Taekwondo's competitive ability.

The research on athletic ability is particularly important to the development of sports. With the increasing importance of sports in China, there are more and more studies on athletic ability. Camagni applied the competition model of global economy to the competition model of Taekwondo and constructed a novel competition model of Taekwondo [1]. Buser et al. found that boys are more likely than girls to choose to compete, and they explained the gender differences in this competitiveness [2]. Vendrell-Herrero and Wilson explained the competitive ability from the policy formulation [3]. Cohen and Tubb drew on the competition model of environmental regulation to study the physical training of athletes [4]. Although the "North American School" rarely sees a complete competitive sports theory, it is based on the characteristics of athletes' competitive practice at different levels, mainly from the perspectives of biology and sports medicine, and studies the molecular biological mechanism and physiological system of athletes' bodies, as well as the working mechanism of athletes, biomechanical

diagnosis and analysis of technical movements, psychological characteristics of athletes and their interventions, basic principles of load stimulation and stress, and specific problems in training and competition practice, such as reaction, fatigue recovery, and sports nutrition, sports rehabilitation, and injury prevention and treatment [5, 6]. However, the theory they put forward is too general, and few studies are aimed at the competitive ability of Taekwondo.

Taekwondo, as a popular, highly appreciated, and competitive sport, has many studies on it. The purpose of Kimberly's study was to find out whether Korean Taekwondo martial arts training is beneficial to undergraduate students (UG) in dealing with psychological stress [7]. Ardalan et al. aimed to determine the anthropometric attributes of judo, karate, and Taekwondo athletes. Through the follow-up survey analysis of 180 athletes in the United States, they determined the indicators of the physical tree measurement of athletes [8]. Su et al. aimed to explore the effects of Taekwondo training on children's cognitive function and academic self-efficacy [9]. Cho et al. distributed a self-completed questionnaire to 401 adolescents over the age of 10 to explore the overall effect of Taekwondo on physical health [10]. Jung and Song aimed to investigate the effects of Taekwondo training on abdominal fat and bone metabolism in obese adolescents [11]. Chang and Hwang aimed to develop an acceptance and commitment therapy- (ACT-) based intervention program for adolescent Taekwondo athletes [12]. However, the content of relevant research pays more attention to Taekwondo exercise and the impact of Taekwondo exercise on physical health, and there is a lack of research on Taekwondo competitive ability.

Expert survey results show that the average score of psychological ability is 4.8 points, the average score of technical ability is 4.9 points, and the average score of tactical ability is 4.9 points. This shows that the indicators selected in the construction of the competitive ability model in this paper are more effective and can be used to evaluate the competitive ability of Taekwondo athletes. The innovation of this paper is as follows: For the detection of model indicators, using the intelligent Internet of Things technology, this paper designs an RFID dynamic detection algorithm. For the algorithm in this paper, in the experiment, it is compared with traditional algorithms, such as FAST, and the throughput rate and time slot are analyzed. It is found that the algorithm in this paper can effectively detect the index data constructed by the model.

2. Ability Monitoring of Taekwondo Athletes Based on Intelligent Network Technology

2.1. Competitive Ability of Taekwondo Athletes. There are more and more competitive Taekwondo athletes, more and more attention is paid to competitive competitions, and the game is more and more enjoyable to watch. The competitive ability of the world's top Taekwondo athletes in the competition is directly related to the victory or defeat of the whole game. Therefore, it is necessary to study the competitive ability of the world's top Taekwondo athletes [13, 14]. Taekwondo techniques and tactics are the core part of Taekwondo's competitive ability and are also the basis of other elements of competitive ability. The research on Taekwondo athletes' competitive ability should start with techniques and tactics. Competitive taekwondo competition is ultimately a test of athlete's scoring ability, and the one with the highest score within the specified time wins. To this end, the athletes on both sides will use various offensive behaviors, such as attacking, counterattacking, or counterattacking. It is not difficult to see the importance of competitive ability in taekwondo competition. Then, how to measure the competitive ability of a world-class taekwondo athlete is very important [15]. At present, there is no clear definition of the concept of taekwondo athletes' competitive ability, and there is no evaluation index and evaluation standard for the world's outstanding Taekwondo athletes' competitive ability. This article will analyze the competitive ability of the world's outstanding Taekwondo athletes from the perspective of technical and tactical methods, screen the competitive ability indicators, collect indicators through video playback, and establish individual scoring standards and grade evaluation standards.

As shown in Figure 1, in the process of Taekwondo sports training or competition, the physical quality of Taekwondo players has a decisive impact on the competition performance. For Taekwondo players, the level of their own balance ability has an important influence on their performance of technical movements on the one hand, and on the other hand, on this basis, the stable performance of various skills of athletes during the competition will directly affect the final ranking of the sport [16]. Muscle strength in the core region was first proposed by European and American experts and researchers, who applied it to experiments on bodybuilding plasticity and exercise recovery after sports injuries. After a period of development, muscle strength in the core area was further simplified as core strength and began to be introduced into sports-related research. As far as the current situation is concerned, China's research on muscle strength in the core area is still at the beginning level, and related research can only be imported from abroad, and no self-independent system has been formed at all, let alone a wider scope. Judging from the current research literature, many experts and scholars believe that the core area refers to the position of people's waist and abdomen, mainly including people's waist muscles and hip muscles. Core strength is the muscle power produced by the muscles in the core area of the human body. Core strength training can maintain the stability of the body during exercise, improve the power transmission capacity of the kinematic chain during the body movement, and reduce the probability of injury, thereby contributing to the improvement of sports performance [17]. Therefore, if you want to achieve excellent results in Taekwondo sports, athletes must have good physical fitness. On this basis, athletes' ability to balance and control their bodies during competition or training directly affects their athletic performance, as shown in Figure 2.

2.2. IoT Health Monitoring Model. Radio Frequency Identification (RFID) has a unique ID in the world, so the RFID system can transmit a signal within a certain frequency to

Figure 1: Some classic movements of Taekwondo.

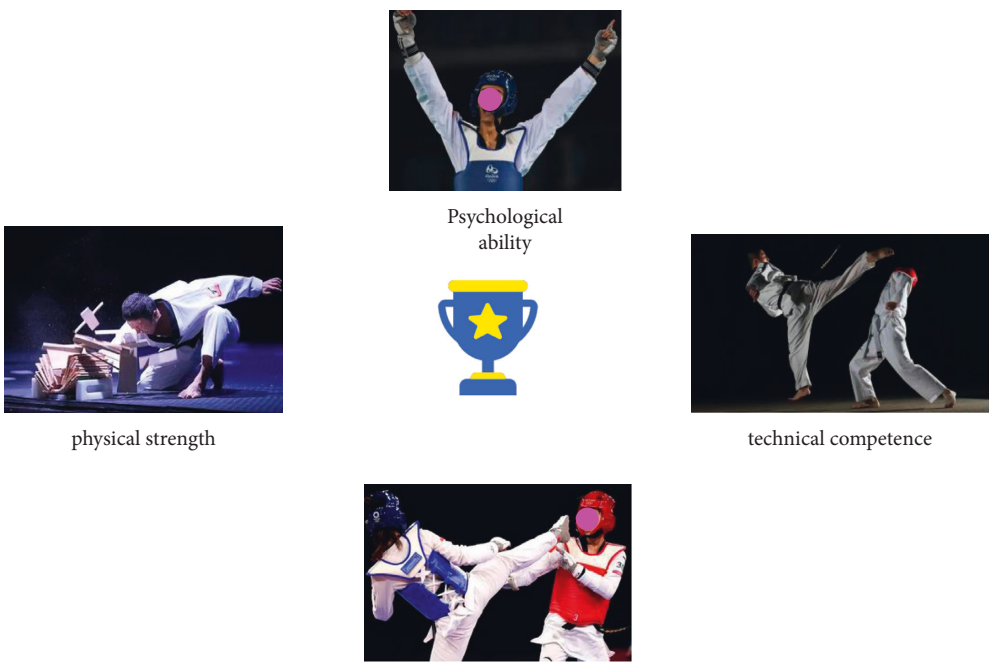

Figure 2: Influencing factors of competitive ability.

quickly identify the ID [18]. It can not only greatly reduce the time-consuming of the algorithm, but also alleviate the influence of factors such as line-of-sight detection and the environment, so it is widely used in identity recognition in life. RFID technology can use radio frequency signals to collect tag information noncontact in a specific frequency band, and the signal can be propagated through non-line-of-sight. In addition, RFID tags have the characteristics of low price, light weight, and

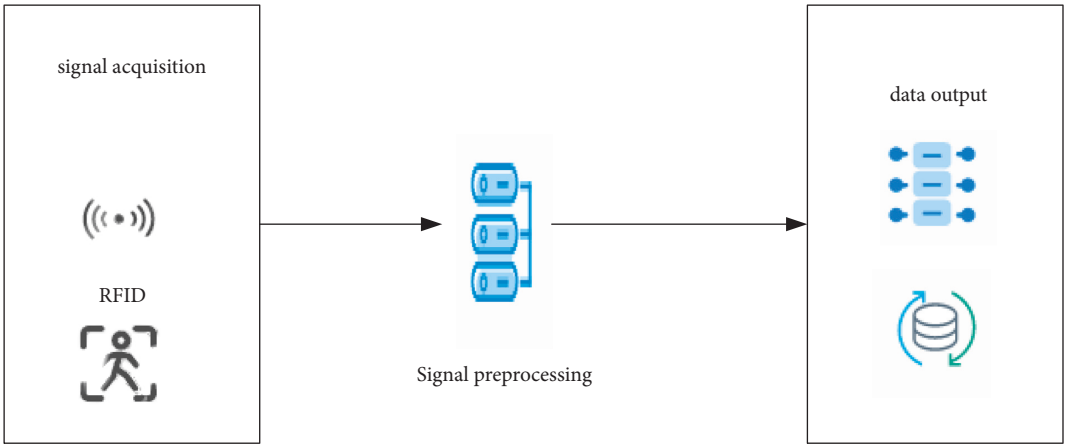

Figure 3: RFID identification process.

large information storage space [19], and are often used in supermarkets, libraries, and other places.

RFID-based monitoring systems are improving people's way of life. According to whether the monitored target needs to wear any related facilities, the monitoring technology is further subdivided into two categories: contact and non-contact. However, the actual situation is that the multipath information is different in different places, and the signal will be reflected to different degrees by different objects, thereby presenting different multipath information. Therefore, this technique can only achieve high-precision recognition in the training environment.

As shown in Figure 3, RFID electronic tags are unique in the world due to a built-in ID code, so they have also been developed in the field of wearable devices. At present, most wearable device research and development companies build RFID tags into wearable devices to realize functions such as mobile payment, bus card swiping, and smart access control. If the RFID electronic tag can be used in the sports testing process of athletes, the identity of the athlete can be bound, and the authenticity of sports testing data can also be guaranteed to a certain extent. It can be seen from the above that with the rapid development of wearable technology and the urgent requirements of current athletes' physical health. In this paper, an athlete's fitness monitoring bracelet is designed that combines various functions of physical health data collection and effective identity matching. It can collect real-time data from athletes' exercise process and centralized testing in various aspects so as to reduce accidents during exercise and prevent data fraud during sports testing [20].

In reality, the body's movement process can generate a variety of data, including exercise time, exercise speed, distance, creatine, and calories. If these data can be efficiently and accurately monitored, the purpose of guiding and adjusting the exercise of athletes can be achieved, and the physical quality of athletes can be improved. In addition, through real-time monitoring of athletes' daily activities, unexpected situations that may occur due to excessive exercise during exercise can be prevented in time, and the occurrence of tragedies during exercise can be minimized. Wearable devices are popular at home and abroad as a device that can monitor human body movement. They can continuously collect data such as movement speed, calories, and sleep status through various sensor chips installed inside them. The main function of the earliest wearable devices is step counting, which can help people count the total number of steps in walking, running, and other sports in a day, and then calculate the distance and calories burned according to related algorithms. With the rapid development of sensor technology and the gradual deepening of kinematics research, smart sports bracelets integrating heart rate sensors, temperature sensors, acceleration sensors, and so on have entered daily life. The new smart sports bracelet not only adds a variety of sports modes to the traditional step counting function, such as walking, running, and swimming, but also provides new functions, such as heart rate detection, body temperature detection, and sleep depth detection. These new smart sports bracelets are not only easy to carry, but also provide people with effective sports information in real time. It can help people plan scientific exercise methods and achieve the purpose of exercising to improve human immunity.

In view of the above shortcomings of the existing monitoring technology, this paper aims to use the RFID system to achieve target monitoring. Even though some related research scholars have designed some monitoring systems using RFID equipment, most of them are designed for equipment-related target monitoring. In addition, a rest interval for user activities is forced; otherwise, the start and end of activities cannot be recognized, which brings certain limitations.

2.3. RFID Anticollision Algorithm Based on Equal-Area Division. When using RFID technology to obtain information such as the positions and movements of Taekwondo athletes, since a tag may be accepted by multiple readers, or a reader has multiple tag responses, the RFID anticollision algorithm should be designed. Aiming at the shortcomings of existing algorithms, this chapter proposes an RFID collision avoidance algorithm (BEAD) based on equal-area division as an RFID collision avoidance algorithm for health monitoring bracelets.

2.3.1. Basic Definition. First, the maximum power recognition range of the reader is determined, and the tags within the recognition range are grouped equally. The number of

labels identified each time is limited, and the existing label estimation algorithm is optimized. On the basis of analyzing the number of labels and time slots, the optimal time slots are adjusted so that the number of labels estimated each time corresponds to the time slots, thereby improving the system throughput. The specific probability is expressed as follows:

$$P(X=k)=C_m^k\cdot\left(\frac{1}{T}\right)^k\cdot\left(1-\frac{1}{T}\right)^{m-k}. \tag{1}$$

In the equation, $k\in[0,m]$ and k are rounded; take $k=-1$, and calculate the probability of one-to-one label selection:

$$P_g=P(X=1)=C_m^1\cdot\left(\frac{1}{T}\right)^1\cdot\left(1-\frac{1}{T}\right)^{m-1}=\frac{m}{T}\cdot\left(1-\frac{1}{T}\right)^{m-1}. \tag{2}$$

The same can be obtained:

$$P_l=P(X=0)=C_m^0\cdot\left(\frac{1}{T}\right)^0\cdot\left(1-\frac{1}{T}\right)^{m-0}=\left(1-\frac{1}{T}\right)^m. \tag{3}$$

Then, $k\geq 2$ at that time; a one-to-many label is expressed as follows:

$$\begin{aligned} a_g^{T,m}&=T\cdot P_g=m\left(1-\frac{1}{T}\right)^{m-1},\\ a_l^{T,m}&=T\cdot P_l=T\left(1-\frac{1}{T}\right)^m,\\ a_e^{T,m}&=T\cdot P_e=T-a_l^{T,m}-a_g^{T,m}. \end{aligned} \tag{4}$$

The specified system throughput rate is 1:

$$S_{RFI\ D}=\frac{a_g^{T,m}}{T}=\frac{m}{T}\left(1-\frac{1}{T}\right)^{m-1}. \tag{5}$$

Derivation of (6) gives

$$\frac{ds}{dm}=\frac{1}{T}\cdot\left(1-\frac{1}{T}\right)^{m-1}+\frac{m}{T}\cdot\left(1-\frac{1}{T}\right)^{m-1}In\left(1-\frac{1}{T}\right), \tag{6}$$

$$T=\frac{1}{1-e^{-1/m}}\approx\frac{1+m^{-1}}{1+m^{-1}-1}=m+1. \tag{7}$$

In practice, a small error is usually required, and the derivative with respect to ξ yields a minimal value:

$$\partial\frac{\varepsilon^2}{k}=2\left[\xi T_{e(n)}-2.3922T_{e(n)}\right]T_{e(n)}. \tag{8}$$

The dynamic prediction weights are

$$\xi=\frac{2.3922\cdot T_{e(n+1)}}{T_{e(n)}}. \tag{9}$$

Substituting ξ into (9), the number of predicted labels in the next round is

$$m=\frac{2.3911\left[T_{e(n)}\right]^2}{T_{e(n-1)}}. \tag{10}$$

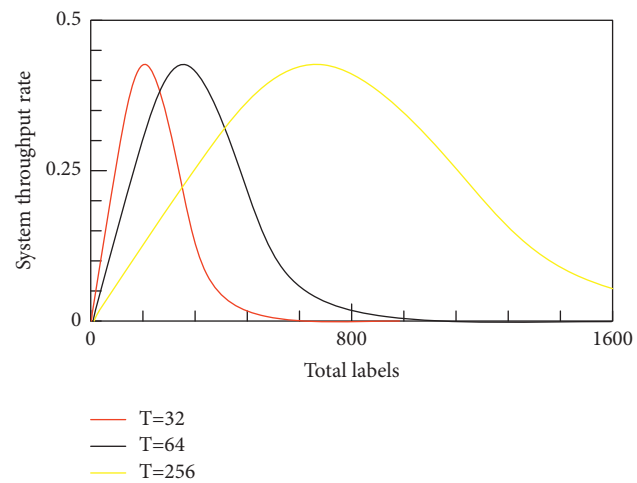

Figure 4: The relationship between the number of tags and the throughput rate.

2.3.2. Adjustment of the Optimal Number of Time Slots. Since the cost of labels is limited by hardware conditions, the number of time slots cannot be allocated arbitrarily, so it is necessary to optimally group labels on the basis of label estimation and dynamically adjust the number of time slots on this basis to further improve the system throughput.

Figure 4 shows the influence trend of the increase in the number of tags on the change of the system throughput under different fixed time slot numbers. It can be seen from the figure that the intersection of the number of two adjacent time slots is the critical point where the number of tags affects the change of the system throughput. The number of adjacent two fixed time slots is substituted into equation (12) to obtain the number of labels corresponding to the number of time slots, and the critical point of the grouping is further obtained. The throughput relationship between the number of adjacent time slots can be expressed as follows:

$$S_1=S_2=\frac{m}{T}\cdot\left(1-\frac{m}{T}\right)^{m-1}=\frac{m}{2T}\cdot\left(1-\frac{1}{2T}\right)^{m-1}. \tag{11}$$

Substitute the entire set of numbers into equation (11) one after another starting from 1 to get

$$m=1+\frac{In2}{In[(2T-1)/(2T-2)]}. \tag{12}$$

For example, when $T=2^2$, take $m=5$; then, 5 is the maximum number of labels when the number of time slots is 2^2, and the grouping results are listed in Table 1.

2.3.3. Algorithm Performance Analysis. In the simulation experiment, it is assumed that the labels are distributed uniformly, the number of system labels is set to 1500, and the initial time slots of the BEAD algorithm, FSA_256 algorithm, and DFSA algorithm are all set to 256. To increase the authority of the test results, let the number of tags start from 50 until the total number of tags increases to 1500. In order to analyze the effectiveness of the BEAD algorithm, the simulation results of each change are recorded, and the

Table 1: Correspondence between time slots and number of packets.

Number of time slots t	2^2	2^4	2^6	2^8	2^8	2^8
Minimum number	1	10	40	160	300	700
Labels maximum number	5	20	80	320	600	1400
Labels grouping number n	1	1	1	1	2	4

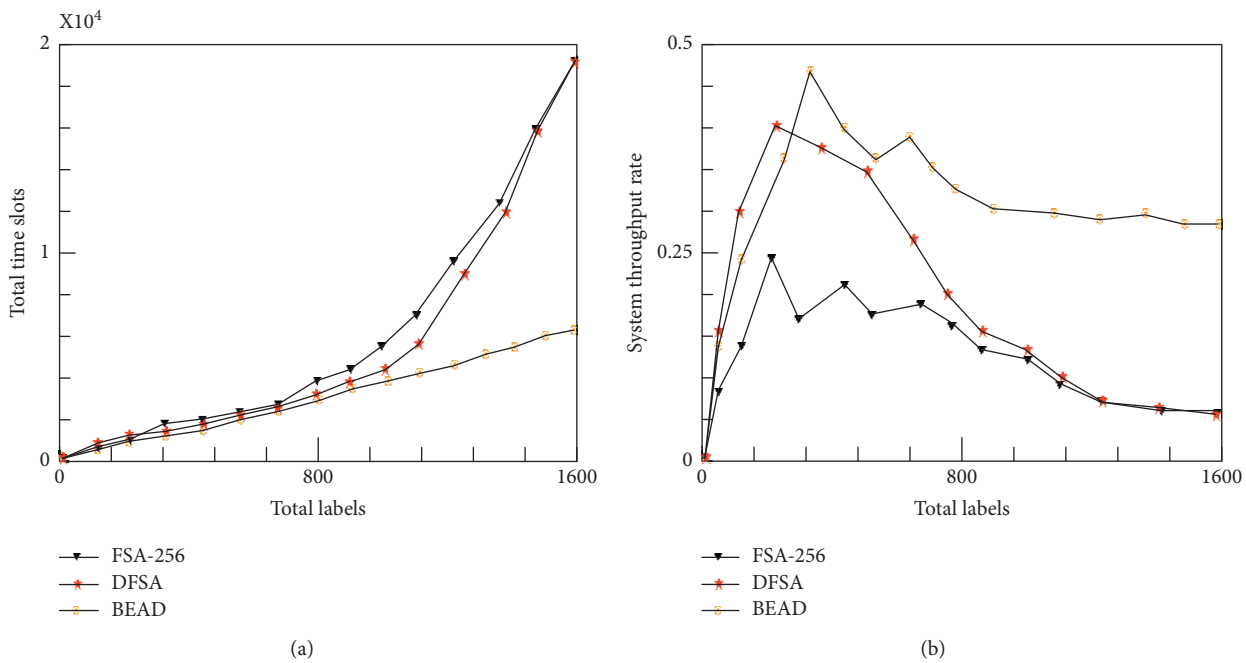

Figure 5: Algorithm performance analysis. (a) Comparison of total time slots. (b) Comparison of throughput.

average of each simulation result is taken. The results are shown in Figure 5. It can be seen that the performance of the algorithm designed in this paper has great advantages in total time slots and throughput.

3. Construction of Athlete Competitive Ability Model

3.1. Indicator Selection. By interviewing relevant experts, reviewing documents, watching video replays, and so on, combined with the components of competitive ability and the characteristics of Taekwondo, this paper determines the primary selection indicators on the basis of previous research. The selected primary selection indicators have relevant literature as reference. In this study, the integrated data and related systems are decomposed into elements, and the decomposed elements are used as evaluation indicators.

The competitive ability of the world's top Taekwondo athletes is composed of many factors, and each factor contains secondary and tertiary indicators. In order to reflect the competitive ability of Taekwondo athletes through indicators, it is necessary to find out all the constituent factors and the indicators contained in them. This requires that the indicators cover a wide range, the content of the indicators should be specific, and the indicators should be operational. In view of the suggestions obtained from the expert interviews, starting from the three dimensions of technical ability, tactical ability, and psychological ability, it is most appropriate to study the competitive ability of the world's top Taekwondo athletes in combination with the athletes in the competition.

Taking into account the characteristics of competitive Taekwondo, combined with relevant research on the technical statistics of fighting projects, it is found that technology and tactics cannot be separated in terms of reflecting competitive ability. In the game, questions such as which technique to use and whether the technique needs to be combined all reflect the tactical ability of the athlete. At the same time, tactical capabilities serve technology. Therefore, Taekwondo techniques and tactics should be fully considered when studying the competitive ability of Taekwondo athletes. Combined with the advice of interview experts, the technical statistics and analysis of Taekwondo projects, and the requirements for quantitative processing of evaluation indicators, this paper will select indicators from the perspective of technical ability and tactical ability and select the quantifiable indicators as the last-level indicators.

Combined with relevant literature and expert advice, this study collects the indicators of the competitive ability evaluation index system of athletes in other sports and then draws on relevant knowledge such as sports training and sports measurement to integrate and classify the extracted indicators. Finally, strictly following the construction principles of scientificity, comprehensiveness, objectivity,

operability, and simplicity in establishing the competitive ability evaluation index system of world outstanding Taekwondo athletes, the primary selection index was determined. The experts interviewed include college Taekwondo teachers, Taekwondo referees, and front-line coaches from various cities (the coaches have more than ten years of teaching experience and the students have won the first place in competitions at or above the municipal level). The details of the experts are shown in Table 2.

The initial selection of indicators includes two first-level indicators of technical ability and tactical ability, and four second-level indicators of technical use times, technical scores, tactical use times, and tactical scores, as well as 18 three-level indicators including the number of straight punches, the number of horizontal kicks, the score of straight punches, and the number of active offensive tactics. The details of the primary selection indicators are shown in Table 3.

3.2. Indicator Selection Results

3.2.1. Survey and Analysis of First-Level Indicator Experts. Expert survey results show that the average score of psychological ability is 4.8 points, the average score of technical ability is 4.9 points, and the average score of tactical ability is 4.9 points. It is generally considered that indicators with an average score of less than 3.5 are inappropriate indicators and should be considered for replacement or deletion under the advice of experts. Obviously, experts believe that it is appropriate to study the competitive ability of competitive Taekwondo athletes from two aspects of technical ability and tactical ability. The survey statistics of the first-level indicator experts are shown in Table 4.

3.2.2. Survey Results and Analysis of Secondary Indicators Experts. The secondary indicators of the primary selection include four items: the number of technical uses, the technical score, the number of tactical use, and the tactical score. Expert survey results show that the average score of technical use is 4.6 points; the average score of technical score is 4.8 points; the average score of tactical use is 4.4 points; and the average score of tactical score is 4.2 points. The average scores of the four secondary indicators are all greater than 3.5 points. As can be seen from Table 5, experts believe that it is appropriate and desirable to study the athletic ability of athletes from the two aspects of the number of technical and tactical use and the score. At the same time, the number of tactical use and the score of tactical score are lower than the number of technical use and technical score.

3.2.3. Survey Results and Analysis of Experts on Three-Level Indicators. There are 18 third-level indicators in the primary selection indicators. Due to the continuous refinement of the indicator system, the selection of indicators should be more specific and more operable; the results of the expert survey are shown in Figure 6.

Table 2: Details of experts.

Name	Job title
Li	Professor
Wang	Professor
Sun	Associate professor
Cai	Lecturer (outstanding athlete)
Sand	Lecturer (outstanding athlete)
Hu	First class referee
Ouyang	Secondary referee
Xie	Secondary referee
Yellow	Head coach
Money	Head coach

Experts put forward suggestions for modification and addition of certain indicators. For example, some experts pointed out that the turning technique includes three techniques: back kick, whirlwind kick, and back spin kick. The importance, usage habits, and scores of these three technologies are different, and it will be more complete to list these three technologies separately. Some experts pointed out that there is a lack of hook kick technology in the index system. Although hook kick technology is not used much in competitions, hook kick technology is also a part of reflecting the athletic ability of athletes. Indicators such as the number of hook skills used and the score of hook skills should be increased.

3.2.4. Coefficient of Variation Analysis. This round of expert questionnaire survey uses WPS Office XLS and statistical software SPSS19.0 to build a database, calculate the standard deviation and mean of each index, and finally obtain the coefficient of variation of each index. The coefficient of variation is used to observe the degree of dispersion of the data. It is generally believed that the coefficient of variation is greater than or equal to 0.15, and the expert coordination of this level of indicators is not enough, and the issue of whether to delete the indicators affecting the coefficient of variation should be considered, as shown in Table 6.

The calculation method of the coefficient of variation is standard deviation/average. After calculation, the average coefficient of variation of the indicators at all levels is obtained. Through the statistics of the coefficient of variation of the indicators at all levels, it can be found that the average coefficient of variation of the indicators at all levels is less than 0.15, which meets the basis for the selection of indicators in this study. Therefore, the indicators formed by consulting materials, interviewing experts, and watching videos were finally determined through two rounds of expert questionnaires and constituted the evaluation index system of the competitive ability of the world's outstanding Taekwondo athletes.

In this paper, the Delphi method is used to determine the weights of each indicator, and the second round of expert questionnaires is conducted. In the expert questionnaire on the importance of the evaluation index of the competitive ability of the world's outstanding Taekwondo athletes, the experts make statistics on the importance of the index and then substitute the statistical data into the weight calculation

Table 3: Evaluation indexes of competitive ability of world excellent Taekwondo athletes.

First-level indicator	Secondary indicators	Three-level indicator
A mental ability	A1 is in a good mood	Good mentality before A11
		Good mentality in A12
		Good mentality after A13
	A2 is in very poor mental state	A21 was in poor mental state before the game
		Poor mental state in A22
		A23 mental state is very poor after the game
B technical ability	Number of times B1 technology is used	Number of times B11 straight punches are used
		Number of times B12 kicks are used
		B13 number of times of use of downslash
	B2 technical score	B21 straight punch use score
		B22 cross kick to use the score
		B23 down hack use score
C tactical ability	C1 tactical uses	C11 offensive tactics used
		C12 counterattack tactics used
		C13 counterattack tactical uses
	C2 tactical score	C21 offensive tactical score
		C22 counterattack tactical score
		C23 attack tactical score

Table 4: Statistics of the first-level indicator expert survey.

	Mental capacity	Technical skills	Tactical ability
Very suitable	8	9	9
Suitable	2	1	1
Generally	0	0	0
Inappropriate	0	0	0
Very inappropriate	0	0	0
The average score	4.8	4.9	4.9

Table 5: Statistical table of secondary indicator expert survey.

	Good mental state	Poor mental state	Technology usage	Technical score	Number of tactical uses	Tactical score
Very suitable	7	9	9	8	7	8
Suitable	3	1	1	1	2	2
Generally	0	0	0	1	1	0
Inappropriate	0	0	0	0	0	0
Very inappropriate	0	0	0	0	0	0
The average score	4.7	4.9	4.9	4.7	4.6	4.8

formula for calculation. Finally, the weight coefficients of the indicators at all levels are obtained, and the calculation formula is the weighted average divided by the sum of the weighted averages.

3.2.5. Indicator Weight Analysis. Figure 7 shows the weight of the world outstanding Taekwondo athlete's competitive ability evaluation index in reflecting the world's outstanding Taekwondo athlete's competitive ability, which constitutes the world's outstanding taekwondo athlete's competitive ability index weight model. Among them, "data weight" is obtained by calculating the scoring results of expert surveys and represents the weight coefficient of indicators at all levels relative to the indicators at the previous level. "Final weight" refers to the proportion of indicators at all levels relative to the overall goal of the world's outstanding Taekwondo athletes' competitive ability.

Data weights are used to calculate individual scoring standards and comprehensive scoring standards and to formulate scoring standards for the competitive ability of world-class Taekwondo athletes. The weights of the first-level indicators of technical ability and tactical ability are 0.5333 and 0.4667, respectively. It can be seen that the importance of technical ability is greater than that of tactical ability. The final weight is used to observe the proportion of each three-level indicator in the entire indicator system. The overall proportion of the number of straight punches is 0.0294, which may be because the number of punches used in the game is far less than that of the leg technique, and the attack efficiency and score of the straight punch are not as high as those of the leg technique. The largest proportion of the total score of the back spin kick is

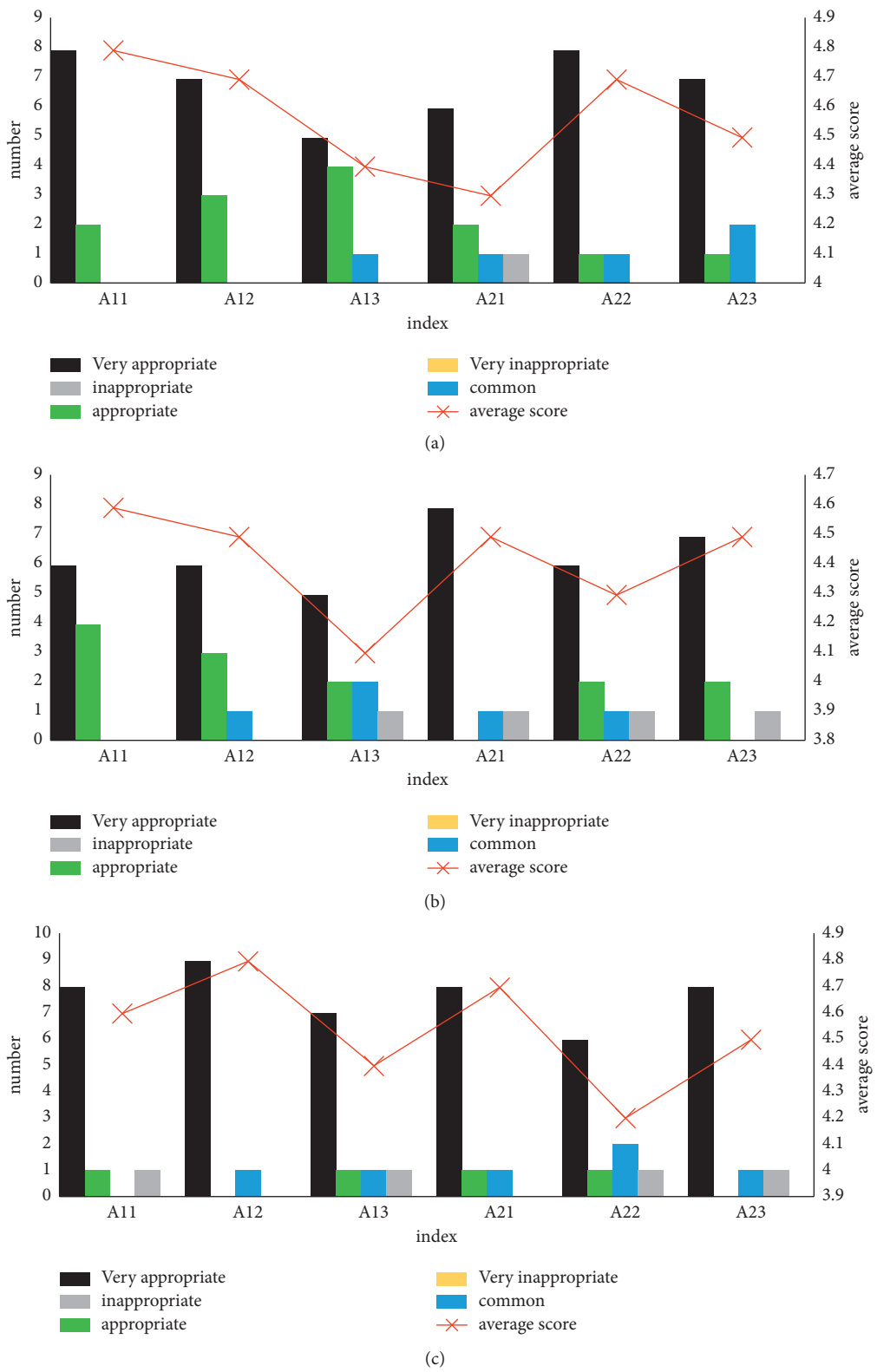

Figure 6: Statistical chart of expert survey on three-level indicators. (a) Statistical chart of expert survey of three-level indicators of psychological ability. (b) Statistical chart of expert survey on three-level indicators of technical ability. (c) Statistical chart of expert survey of third-level indicators of tactical ability.

Table 6: Statistics of coefficient of variation of the second round of expert questionnaires.

Indicator level	Mean coefficient of variation
First-level indicator	0.0901
Secondary indicators	0.1301
Third-level indicator	0.1305

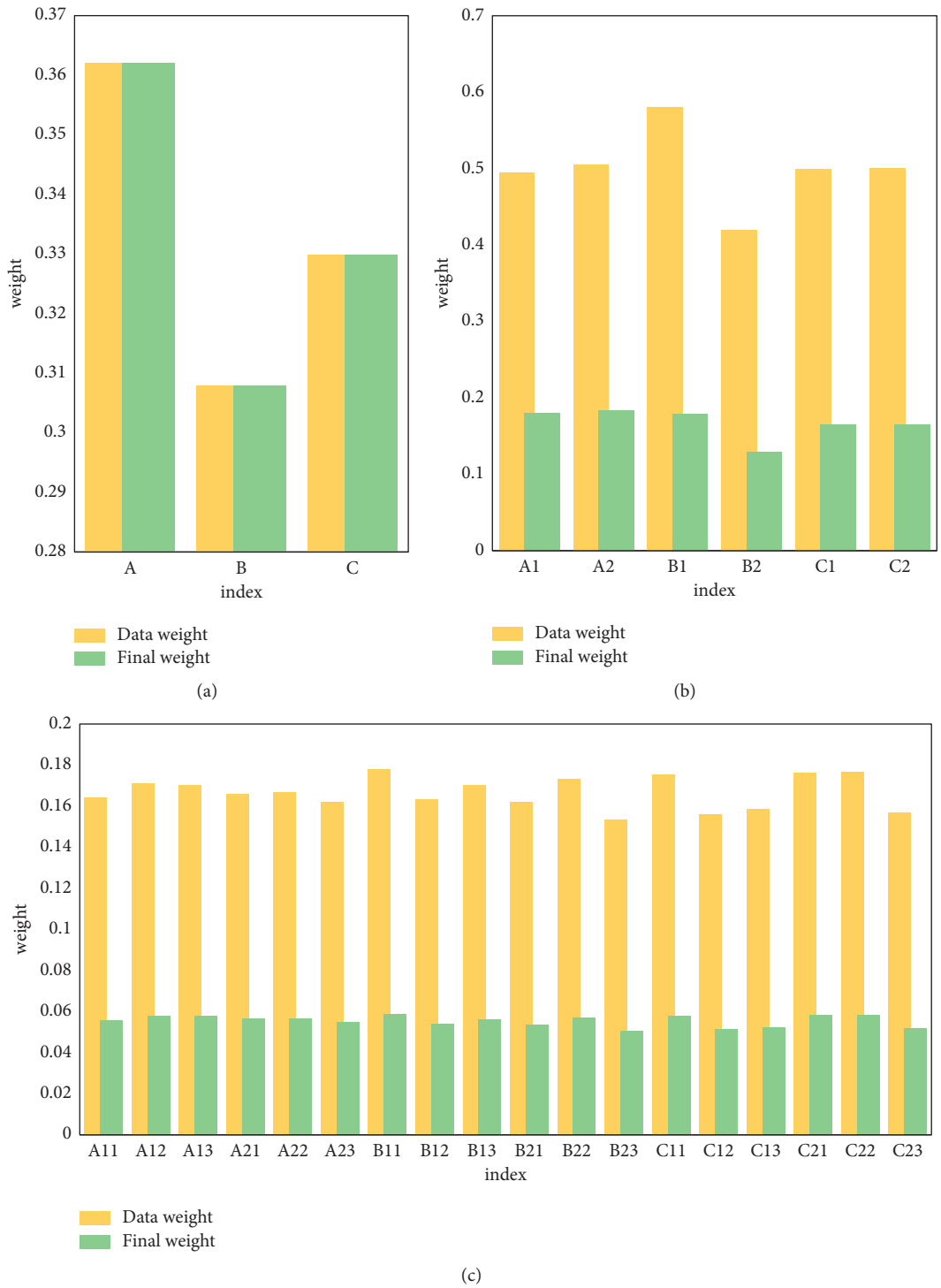

Figure 7: Weights of competitive ability evaluation indicators. (a) Primary indicator. (b) Secondary indicator. (c) Three-level indicators.

Table 7: Details of elite athletes at all levels.

Gender	Level	Numbering
Female	46 kg	1
	53 kg	2
	62 kg	3
	73 kg	4
	Above 73 kg	5
Male	54 kg	6
	63 kg	7
	74 kg	8
	87 kg	9
	Above 87 kg	10

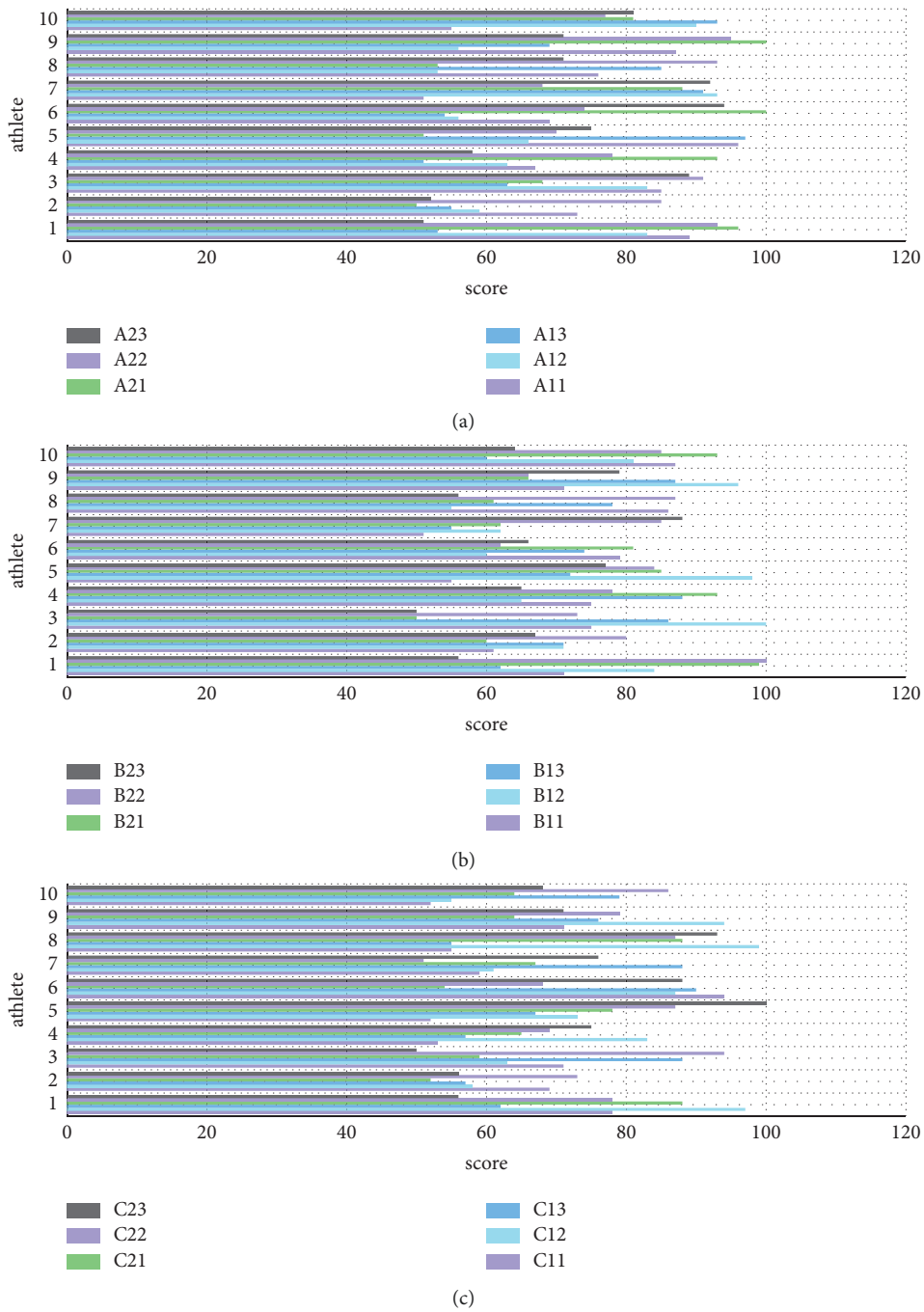

Figure 8: Analysis of the competitive ability of ten athletes. (a) Athlete mental ability score. (b) Athlete technical ability score. (c) Scoring of athlete's tactical ability.

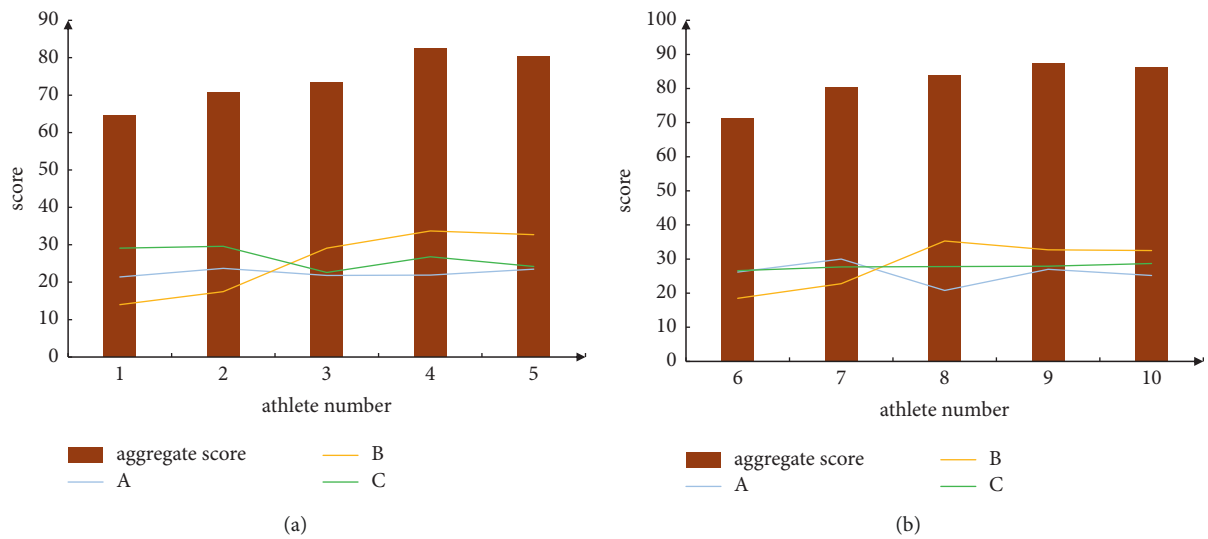

Figure 9: Competitive ability ranking. (a) Competitiveness of female athletes. (b) Men's athletic ability.

0.0440, mainly because the current rules support and advocate the use of difficult legwork and turning techniques for athletes with high concealment and high lethality. The technical score of the backspin kick is not only high, but also hitting the head position can easily cause the opponent to lose their will, thus gaining an overwhelming advantage.

3.3. Evaluation Results of Competitive Ability of Taekwondo Athletes. In order to verify the effectiveness of the evaluation indicators, this paper is divided into two experiments to verify. The first experiment is the evaluation of the competitive ability of the world's elite athletes. Through video analysis and expert evaluation analysis, the mental ability, technical ability, and tactical ability of the selected ten world-class Taekwondo athletes were judged, and the competitive ability of the athletes was divided through the index model.

In the second experiment, 10 random students from a class in a martial arts school were selected. Through field tests, their mental ability, technical ability, and tactical ability were judged, and the athletes' competitive ability was divided by the index model.

The purpose of constructing the evaluation standard is to measure the competitive ability of the world's top Taekwondo athletes. The individual evaluation results can be used to compare the athletes on a certain index horizontally, and it cannot be compared as a whole, nor can an overall score be obtained. Therefore, it is necessary to construct a comprehensive evaluation standard for the competitive ability of the world's outstanding Taekwondo athletes. The comprehensive evaluation result is calculated on the basis of the individual evaluation results combined with the contribution of each index to the entire system (the weights of indicators at all levels) so as to achieve the purpose of evaluation.

3.3.1. Evaluation Results of Elite Athletes. Because the three-level index determined in this study is a dynamic value, that is, the competitive ability of athletes in the face of different opponents is also different, it is unscientific to judge the competitive ability of a competitive Taekwondo athlete by only one game. Therefore, when we evaluate the competitive ability of the world's top taekwondo athletes, we should observe the athlete in many games.

This paper selects 5 athletes from 4 Olympic levels of men and women as statistical objects. The specific conditions of each athlete are shown in Table 7.

According to the individual scoring standard, use the COUNTIF function in the Excel table to calculate the scores of the world's top Taekwondo athletes in each indicator. The method for determining the score is that when the statistical data is between the two scores, the smaller score is taken as the single indicator score of the world's elite athletes. When the scores corresponding to the statistical data are the same, the maximum value is taken as the single index score of the world elite athletes. For example, when the score of the A210 back kick score is less than 0.60, the score is 50 points. According to this method, the individual index scores of the world's outstanding Taekwondo athletes are calculated, as shown in Figure 8.

The scores and rankings of each athlete's competitive ability are calculated, and the details are shown in Figure 9.

From Figure 9, it can be roughly seen that athletes with higher weight classes have higher competitive abilities, which is consistent with what we usually think of as higher weight classes, stronger, and more competitive abilities. It is worth noting that the model evaluation found that the higher the body weight, the stronger the competitive ability.

3.3.2. Evaluation Results of Students in Martial Arts Class. This time, 10 students were randomly selected for the test. The evaluation indicators in this article were used to test the competitive ability and rank. The ranking results are compared with the ranking of the class to compare the evaluation effect of the model.

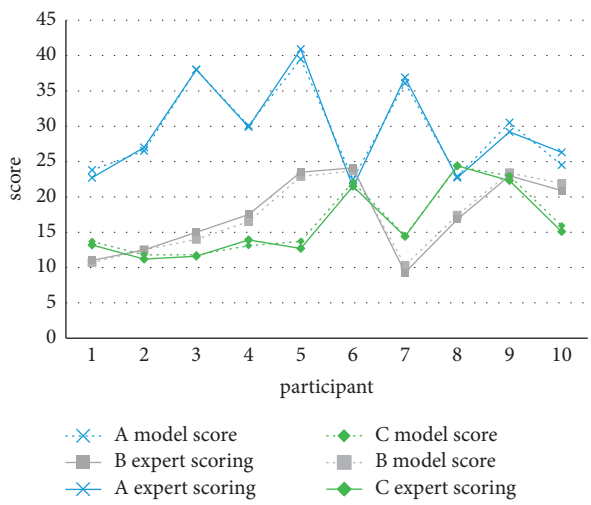

Figure 10: Model scoring versus expert scoring.

For the evaluation of mental ability, this paper measures the heart rate, respiratory rate, and body temperature before, during, and after the competition through the intelligent Internet of Things technology so as to comprehensively evaluate the mental ability of the participants. For technical ability and tactical ability, the action in the index is analyzed by evaluating the strength, speed and completeness of the action on the spot. Finally, compare the scores of the model evaluation with the on-site scores of the expert group teachers, and the results are shown in Figure 10.

4. Conclusions

Along with the outstanding achievements of Chinese excellent Taekwondo athletes in world competitions, Taekwondo has attracted more and more enthusiasts to participate in competitive competitions with its unique charm, in particular, the first-line Taekwondo gymnasts in various cities and the big athletes Taekwondo athletes and so on. This paper establishes an evaluation model for the competitive ability of Taekwondo athletes, including three second-level indicators and 18 third-level indicators of psychological ability, technical ability, and tactical ability. The validity of the evaluation model in this paper is also proved by experiments. However, there are also some defects in the evaluation model; for example, there are few subjects in the experiment, and there is no experiment for athletes and players from many countries, which leads to a large limitation of the model. Therefore, in the follow-up experiments, the author will take this as the object to conduct more in-depth research.

Data Availability

Data will be 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.

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Research Article

Topological Optimization Design for a Multiscale Femoral Prosthesis Model Based on Homogenization Method

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Femur is a thigh bone in humans, which is particularly prone to injury and difficult to mend if damaged. The stress shielding effect is caused by a change in bone mechanics transmission route as a result of femur bone damage. The formation of a porous structure provides a better solution to the problem of stress shielding effect reduction. The porous material is basically a solid which has empty space(s) which is not covered by the primary structure of particles that build up the solid's structure. Traditional porous materials have a uniform density distribution in their microstructure. The density distribution of a material should be established according to different loads in each location of the material to completely represent its characteristics. In this paper, to acquire the ideal density distribution of porous materials and construct high-performance variable-density porous structures, topological optimization is applied into the design of the lattice structure. According to a structure constructed utilising individualised parameters paired with computed tomography (CT) data of the human femur, a topological optimization design of a multiscale femoral prosthesis model based on the homogenization approach is presented. Experiments on different femoral prosthesis architectures revealed that variable-density porous prostheses have superior material and stress distributions than equal-density porous prostheses under the same stress and successfully decreased femoral stress shielding to improve prosthetic stability.

1. Introduction

The femur is a bone in the human body that is found in the thigh area. It is the body's longest and the most powerful bone. It is an important component of the human capacity to stand and move. Many vital muscles, tendons, ligaments, and components of the human circulatory system are also supported by the human femur. The femur bears the majority of the human body weight as one of the primary load-bearing elements of the lower limbs. This bone is very easily injured and difficult to mend after it has been damaged. Furthermore, arthritis, osteoporosis, and other linked disorders have received more attention in aging people [1].

Total hip replacement is the most effective way to solve injury and inflammatory pain of the femoral joint. However, many postoperative complications have not been solved completely. The proportion of young patients who considerably exercise and will be rebuilt after the operation has also been increasing [2]. The cause of postoperative adverse reactions is the mismatch between elastic modulus of implant and host femur. Wolff's law states that the implant with the highest elastic modulus carries a portion of the load that is initially carried by the femur [3]. This syndrome causes bone resorption by altering the direction of mechanical transmission on the femur and lowering the load on the femur [4]. Reducing the stress shielding effect caused by change in the transmission path of bone mechanics is the problem to be solved [5].

A porous substance is the one that has pores (voids) in it. The "matrix" or "frame" refers to the skeleton component of the material. A fluid (liquid or gas) is usually injected into the pores. Although the skeleton material is normally solid, structures such as foams might benefit from the notion of porous materials [6]. Along with rapid development of 3D

printing technology, the emergence of a porous structure better solves the problem of reducing the stress shielding effect. The introduction of porous structure can greatly reduce the elastic modulus of a metal, which causes the elastic modulus of prosthesis to be similar to that of a natural bone. Stress shielding is reduced as a result, and the implant-bone tissue combination can be improved [7]. Node connectivity, porosity, pore width, and the overall material of unit cells influence the mechanical and biological characteristics of unit cells in completely porous biomaterials [8]. According to the type of unit body structure, porous structures for additive manufacturing can be divided into three types: imitated dot array of metal lattice, curved-surface porous structure generated by controlling the implicit function, also known as a three-period minimum curved-surface porous structure, and the unit body obtained after topological optimization [9].

Numerous researches have been undertaken on developing the crystal lattice structure and its performance due to the simplicity of the crystal lattice design and its outstanding qualities, such as being light and having high strength [10, 11]. Arabnejad et al. [12] designed a hip stem filled with conceptualized two-dimensional lattice to optimize the structure with bone resorption and interface failure as conditions to control the density. The design has been proved to result in a more uniform transfer of force from the prosthesis to the femur, reduce bone resorption, and lower the fatigue strength on the stem of the prosthesis. Oladapo et al. [13] designed five kinds of hip bone implants with composite porous cell microstructure. The results showed that controllable homogenization, porosity, and particle size distribution are beneficial in increasing the cell infiltration and biological integration of hip implant composites. Seharing et al. [14] compared and analyzed the mechanical properties of cubic and eight-axis truss gradient lattice structures. The displacement is identified by using finite element analysis based on the simulation of uniaxial compression. The results showed that the cubic gradient lattice structure has the best mechanical properties under appropriate relative density and pore diameter, which is suitable for bone implant. Eldesouky et al. [15] proposed a novel design of tibial implant with a porous rhombic dodecahedron structure. Compared with the solid titanium implant, the clinical performance of such tibial-knee joint implants is improved, which lowers the stress shielding. Zhang et al. [16] proposed a step topology design of functional gradient porous biomaterial with a diamond unit structure to simulate the structure of the femoral shaft. Selective laser melting is selected by taking Ti-6Al-4V powder as the raw material. The defect coupling model predicted the Young's modulus and yield stress of functional gradient porous biomaterials that revealed a considerable yield at the bearing location.

The three-period minimum curved-surface structure is a minimum surface with complex 3D topological spatial structure [17, 18]. This structure has high specific surface area, high porosity, and high long-range ordered structure [19]. Its internal structure is interconnected, and surface is smooth. Such a porous structure is useful for constructing bone implants [20, 21]. Ma et al. [22] designed a gyroid double implicit curved-surface porous structure (double-gyroid) by using the Parametric Technology Corporation (PTC) software and gyroid. They prepared a double-gyroid structure by using laser selective melting technology. From the compression test and hydrodynamics simulation, the mechanical performance and fluid permeability are obtained. The structure is predicted to be suitable for cell culture and medical implant. Corona–Castuera et al. [23] designed and fabricated personalized stainless steel partial hip implants by using tomography data and self-supporting three-period minimum curved-surface structure. The mechanical properties of the implants during compression are adjusted by using an internal rotating element structure. The design and manufacture of implants are developed by considering the clinical conditions of specific patients. The quality of the different types of bone tissues can be adjusted to meet specific clinical requirements. Vijayavenkataraman et al. [24] studied the design of porous bone implant based on the three-period minimum curved surface, and this design is made by using photoetching ceramic manufacturing technology. A total of 12 different initial surface structure elements are considered. The results show that the selection of materials and the design of porous-based three-period minimum curved surface had led to markedly lower compression modulus of the structure than that of the natural bone. Therefore, the design method can be used in the design of bone implant to alleviate the stress shielding effect. Song et al. [25] proposed a design and optimization method for the porous structure of customized root simulated implant. The Procter and Gamble (P and G) structures with four kinds of porosity are designed and prepared by using the three-period minimum curved surface as the cubic samples. The Young's modulus, Poisson's ratio, and yield strength of each sample are measured by a compression test. The stress distribution at the interface between the tailored implant and the surrounding bone tissue is studied using finite element analysis under various pore structures and porosities. The results show that the porous implant constructed by using the three-period minimum curved surface can lower the stress shielding effect.

The basic principle of designed porous element based on the topological optimization method is the specific load and boundary conditions as well as design and nondesign areas are set in the cubic space by using topological optimization algorithm. In order to create a unit structure with a certain porosity, the relative density is used as the weight reduction goal when creating topological optimization conditions. Simoneau et al. [26] developed a disordered porous-structure filling at the top section of the prosthesis stem, which is proven to better distribute stress and enhance mechanical distribution of the prosthesis. Deering et al. [27] designed a porous scaffold by using selective Voronoi tessellation and priority sowing technology to simulate the natural structure of trabecular bone. During polyhedron expansion, a preference texture is produced in the seed void in the original volume to change the implant's support direction. Anisotropy is digitally characterized by the mean intercept length

and star-shaped volume distribution to determine the similarity with the trabecular direction. Nicali et al. [28] built the bottom structure of the prosthesis to be more efficient than a prosthesis created using standard approaches by taking into account the patients' masticatory biomechanics. The ultimate structural volume is 2% of the starting model, which differs significantly from the standard model. The material is distributed according to the load point, the direction and modulus of the applied force.

A new topological optimization method for variable-density lattice structure is proposed in this paper. A personalized porous prosthesis that can fit the human femur is designed based on the CT data of human femur. Then, based on the homogenization method, the topological optimization design of a multiscale femoral prosthesis is achieved. The numerical analytical results of the femoral stress shielding by three prostheses are compared by combining the mechanical performance of total solid prosthesis, uniform porous prosthesis, and variable-density porous prosthesis.

The rest of the paper is structured according to the following section: the topological optimization model of the multiscale lattice structure based on the homogenization method is present in Section 2, Parametric modelling of femoral prosthesis is discussed in Section 3, while results and analysis are delivered in Section 4. Finally, the paper is concluded in Section 5.

2. Topological Optimization Model of Multiscale Lattice Structure Using Homogenization Method

This section is divided into the following sections.

2.1. Calculation of Mechanical Properties for a Lattice Structure. The lattice microstructure with uniform periodic array is classified as the continuum. The homogenization process might be used to produce identical mechanical characteristics. The microstructure lattice cell is a rhombic dodecahedron. The volume percent of the lattice cell are stated as follows:

$$x_e = \frac{V_s}{V}, \tag{1}$$

where, x_e is the relative density of lattice cell (volume fraction), V_s is the volume of lattice cell's solid component, and V is the volume of lattice cell.

The equivalent elastic modulus of the lattice structure $\mathbf{E}^H_{\mathrm{ijkl}}$ can be calculated as follows:

$$E^H_{ijkl} = \frac{1}{|V|}\int_{V_s} E_{ijmn} M_{mnkl} dV, \tag{2}$$

where E_{ijkl} is the local elastic modulus, this is the elastic modulus for the solid component of the lattice cell's material, and M_{ijkl} refers to $\overline{\varepsilon}_{ij}$, the local structure tensor ε_{ij} related to the macro-strains and micro-strains as follows:

$$\varepsilon_{ij} = M_{ijkl}\overline{\varepsilon}_{ij}. \tag{3}$$

M_{ijkl} can be calculated as follows:

$$M_{ijkl} = \frac{1}{2}\left(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk}\right) - \varepsilon^{*kl}_{ij}. \tag{4}$$

In (4), δ_{ij} is the Kronecker delta and ε^{*kl}_{ij} is the microstructure strain corresponding to $\overline{\varepsilon}_{kl}$, the component kl of the macro-strain tensor.

Micro-strain can be expressed as follows:

$$\begin{aligned}\sigma_{ij} &= E_{ijkl} M_{klmn}\overline{\varepsilon}_{mn},\\ &= E_{ijkl} M_{klmn}\left[\left(E^H_{pqmn}\right)^{-1}\overline{\sigma}_{pq}\right].\end{aligned} \tag{5}$$

To avoid the repeated use of the homogenization method and to speed up the iteration rate, this paper is aimed to calculate the equivalent mechanical properties of the lattice cells at different sampling sites by sampling the density and fit the functional relationship between the equivalent mechanical properties and the relative density of the lattice cells. The samples are collected in equal density intervals of the relative density in the range of 0–1. The corresponding equivalent mechanical properties are calculated by the homogenization method. Based on the polynomial interpolation formula, the relationship between the properties of the lattice cell and relative density is fitted into the function formula. Figure 1 shows the functional relationship between the equivalent elastic modulus $\overline{E}_{ii}$, shear modulus $\overline{G}_{ii}$, Poisson's ratio $\overline{\nu}_{ij}$, and relative density of cells x_e. Among these variables, E_s is the elastic modulus of the solid material, while ν_s refers to the Poisson's ratio of the solid materials. The cube in Figure 1 is a rhombic dodecahedron structure called a lattice structure cell. The function curve in Figure 1 is obtained by the least squares fitting. Quadratic polynomial fitting provides the elastic and shear modulus, whereas cubic polynomial fitting provides Poisson's ratio. The parameters related to the fitting function are shown in Table 1, in which R^2 represents the fitting accuracy. If R^2 is closer to 1, the fitting accuracy is higher. If R^2 is closer to 0, the fitting accuracy is lower. The fitting function could be directly used in the iterative process of topological optimization to avoid monotony caused by the repeated use of homogenization in each iteration and speed up the iteration.

2.2. Multiscale Topological Optimization. The homogenization approach is used to propose the density method. Essentially, the classic density technique generates a distribution of 0 and 1, which is related to macrostructure optimization. The topological optimization design of the lattice structure included the microscale, which involved the qualities of a microstructure, in addition to the macroscale.

The lattice cell corresponds to the finite element one by one in the iteration of the density method. The equivalent elastic modulus E_e (i.e., unit elastic modulus) of the lattice structure cell is calculated rapidly according to the fitting formula in Table 1, and then, the numerical solution is performed as follows:

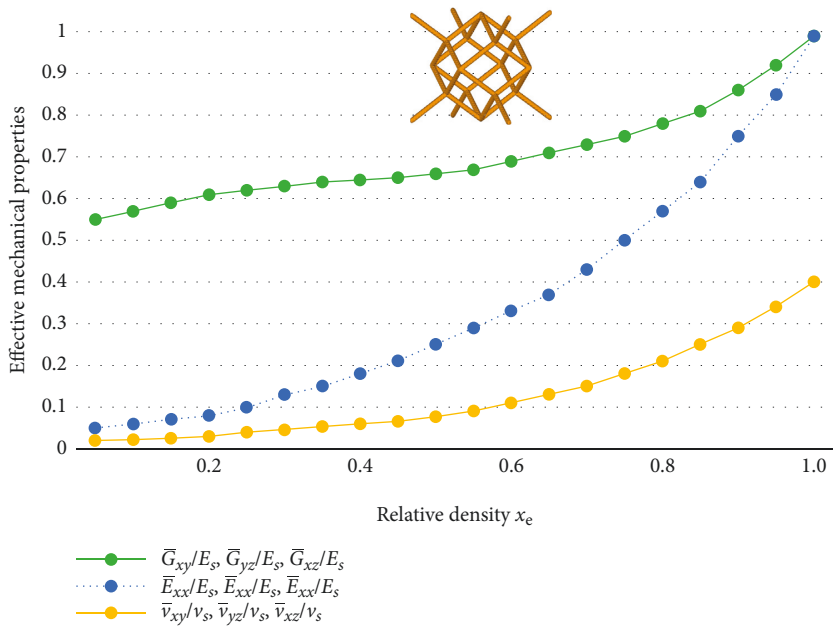

Figure 1: Equivalent mechanical properties of the lattice cell.

Table 1: Functional relationship between equivalent mechanical properties and relative density $\mathbf{x_e}$ of lattice cells.

Equivalent mechanical properties	Fitting function	Fitting accuracy (R^2)
$\overline{E}_{\mathbf{xx}}/\mathbf{E_s} = \overline{E}_{\mathbf{yy}}/\mathbf{E_s} = \overline{E}_{\mathbf{zz}}/\mathbf{E_s}$	$0.745x_e^2 + 0.101x_e + 0.022$	0.998 57
$\overline{G}_{\mathbf{xy}}/\mathbf{E_s} = \overline{G}_{\mathbf{yz}}/\mathbf{E_s} = \overline{G}_{\mathbf{xz}}/\mathbf{E_s}$	$0.515x_e^2 - 0.098x_e + 0.031$	0.997 79
$\overline{\nu}_{\mathbf{xy}}/\nu_{\mathbf{s}} = \overline{\nu}_{\mathbf{yz}}/\nu_{\mathbf{s}} = \overline{\nu}_{\mathbf{xz}}/\nu_{\mathbf{s}}$	$0.449x_e^3 - 0.644x_e^2 + 0.292x_e + 0.706$	0.989 65

$$\begin{aligned} x &= (x_1, x_2, \ldots, x_n)^{\mathrm{T}}, \\ c(x) &= U^{\mathrm{T}}KU \\ &= \sum_{e=1}^{N} E_e(x_e) u_e^{\mathrm{T}} k_e u_e, \\ s.t. &\begin{cases} V\dfrac{(x)}{V_0} = f, \\ F = KU, \\ 0 < x_{\min} \le x_e \le 1, \end{cases} \end{aligned} \tag{6}$$

where, x_e refers to the design variable (unit relative density), and its value is in the range (0, 1), $x_{\min}$ refers to the minimum relative density to avoid occurrence of singularity, x refers to the vector of design variables, N refers to the number of design variables, c refers to the overall flexibility, E_e refers to the unit elastic modulus (equivalent to the elastic modulus of the cell), U refers to the global displacement matrix, F refers to the global stress matrix, K refers to the global stiffness matrix, k_e refers to the unit stiffness matrix, u_e refers to the unit displacement matrix, $V(x)$ and V_0 refer to the solid and total volumes of the design domain, respectively, and f refers to the volume fraction.

Different methods are used to solve the optimization results. The optimization criterion algorithm is common. The design variables could be iterated constantly in the solution process. The iterative process depended on the following heuristic algorithm

$$x_e^{\text{new}} = \begin{cases} \max(x_{\min}, x_e - m), & \text{if } x_e B_e^{\eta} \le \max(x_{\min}, x_e - m), \\ x_e B_e^{\eta}, & \text{if } \max(x_{\min}, x_e - m) < x_e B_e^{\eta} < \min(1, x_e + m), \\ \min(1, x_e + m), & \text{if } x_e B_e^{\eta} \ge \min(1, x_e + m), \end{cases} \tag{7}$$

where, m represents the maximum variation; and η refers to the numerical damping coefficient. B_e could be solved as follows:

$$B_e = \frac{-\partial c/\partial x_e}{\lambda\ \partial V/\partial x_e}, \tag{8}$$

where λ refers to the Lagrangian function.

Contrary to the traditional density method, the new technique does not have a penalty factor. The sensitivity of the objective function is derived on the basis of the fitting formula in Table 1 as follows:

$$\frac{\partial c}{\partial x_e} = (1.098x_e + 0.102)u_e^{\mathrm{T}} k_e u_e. \tag{9}$$

When the unit volume is used in each element, the sensitivity of the volume is as follows:

$$\frac{\partial V}{\partial x_e} = 1. \tag{10}$$

To summarise, the above represented the essential principle of topological optimization of the lattice structure using the homogenization method: The fitting function of comparable mechanical characteristics of the rhombic dodecahedron lattice cell is calculated and fitted using the homogenization approach. By merging the density approach with the structure topological optimization model of the minimal compliance issue under volume constraints, a structural topological optimization model of the minimum compliance problem under volume constraints is created. The unit mechanical characteristics of the new technique are derived using the homogenization method, rather of the previous density method. There is no penalty factor employed. The fitting function equation is used to calculate sensitivity. As a result, the optimization results comprise a series of gray units with the relative densities ranging from 0 to 1. A variable-density lattice structure would eventually emerge from these gray components.

2.3. Parametric Modelling of Variable-Density Lattice Structure. To construct the lattice structural morphology based on discrete elements, extracting the information of key position is necessary to assist the modelling. As shown in Figure 2, the spatial position of each lattice cell could be positioned by extracting the node coordinates of the element. In terms of equal-density lattice structure, array modelling could be directly performed according to the geometric parameters of the cell, as shown in Figure 2(b). If the node position coordinates are retrieved without addressing the transition between cells with varying densities for a variable-density lattice structure, the problem of unequal connectivity between cells will arise. In the case of the X-shaped cell, the connection's strength is decided by the weakest cell at the time shown in Figure 2(c). To solve a nonsmooth connection, extracting the adjacency of each unit and the connection between unit nodes, in addition to the node information, is required to transform the unit density into the node density and construct the smooth variable-density lattice model based on the node density shown in Figure 2(d).

The autogeneration of the geometric model for the variable-density lattice mainly included four parts as shown in Figure 3: (1) acquisition of unit density distribution after optimization; (2) calculation of the node density; (3) construction of the cell geometric model, and (4) generation of the lattice geometric model.

After optimization, the density of the unit density can be retrieved from the topological optimization result. The following weighted average equation is used to determine node density:

$$\rho_{nj} = \frac{\sum_i x_{ei} V_{ei}}{\sum_i V_{ei}}, \tag{11}$$

where, ρ_{nj} refers to density of the jth node, x_{ei} and V_{ei} refer to density and volume of the j element adjacent to node i, respectively.

Nonuniform rational B-spline is used to describe the model in the existing mainstream computer-aided design (CAD) system. Its essence is an element expressed in the form of the tensor product. As expressing models with complex geometry, this element is usually expressed topologically by boundary representation (B-Rep) and format of the constructed solid geometry (CSG).

The geometric model of the cell is constructed based on the B-Rep method. The geometric and topological information of the model are constructed parametrically according to the spot, line, and surface from bottom to top. The expression of B-Rep is depicted in Figure 4 using the X-shaped cell in Figure 3 as an example. The parametric construction and operation of various geometric models based on the spot, line, and surface can be achieved from bottom to top according to the topological information of the shape in the B-Rep structure once the B-Rep structure is established.

For the variable-density lattice structure, adjusting the coordinate position on the top of the cell according to the node density is necessary. Then, the geometric model of the deformed cell is constructed by constructing the line and surface based on the B-Rep relation. After the deformed cells corresponding to various elements are constructed, the parametric model of complex lattice structure could be constructed by CSG through intersection, union, difference, and other operations. In CAD system, geometric models are expressed by boundaries, while 3-dimensional (3D) solid models are described through their surfaces. Therefore, the above methods can be used in the surface parametric construction of 3D models to realize the autogeneration of complex 3D variable-density lattice models.

2.4. Algorithm Implementation. The basic flow of topological optimization algorithm for multiscale lattice structure based on the homogenization method is shown in Figure 5.

The proposed method is based on the homogenization and density methods. First, equivalent mechanical properties of the lattice cell are determined by using the homogenization method and fitted as functions with relative density of the lattice cell. Then, using the density approach in MATLAB, iteration is optimized using the relative density of microstructure cells as the design value and the minimal flexibility as the goal function. The fitting formula in Table 1 is used to compute the equivalent mechanical characteristics of cells. The equivalent volume element approach is used to equate the lattice cells to dense solid components. The finite element problem is solved via Analysis System (ANSYS). The relative density distribution of the element, element nodes,

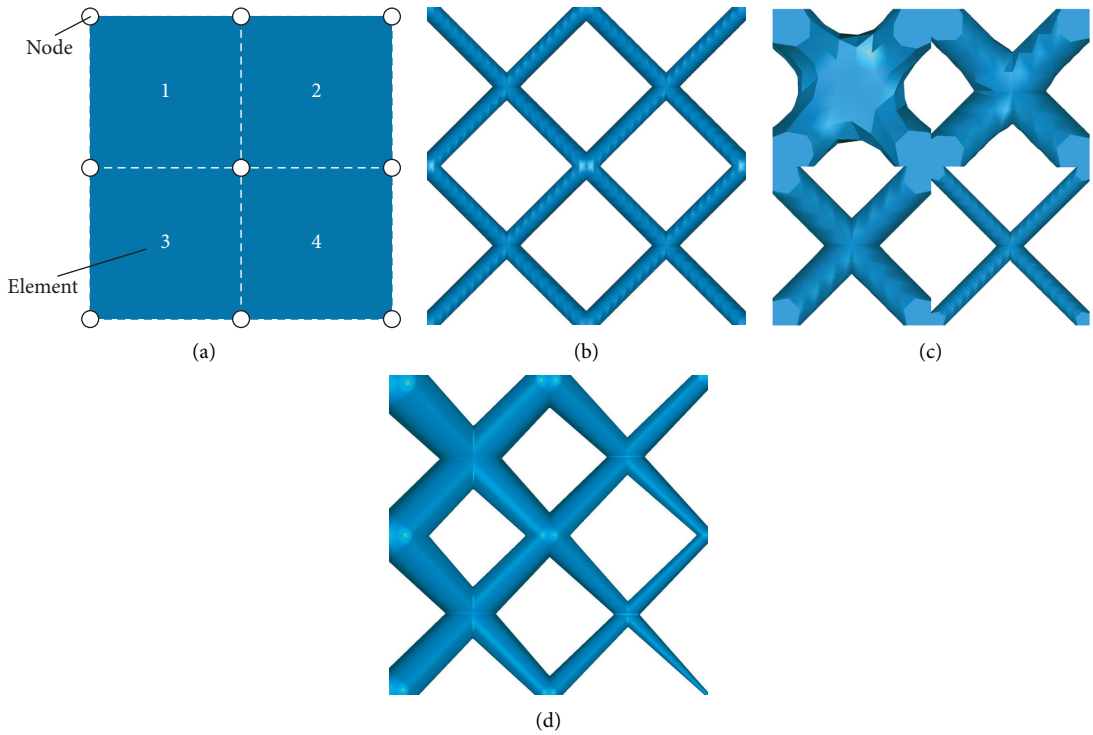

Figure 2: Example of the lattice model based on the discrete element: (a) unit node model; (b) equal-density lattice model; (c) nonsmooth variable-density lattice model; (d) smooth variable-density lattice model.

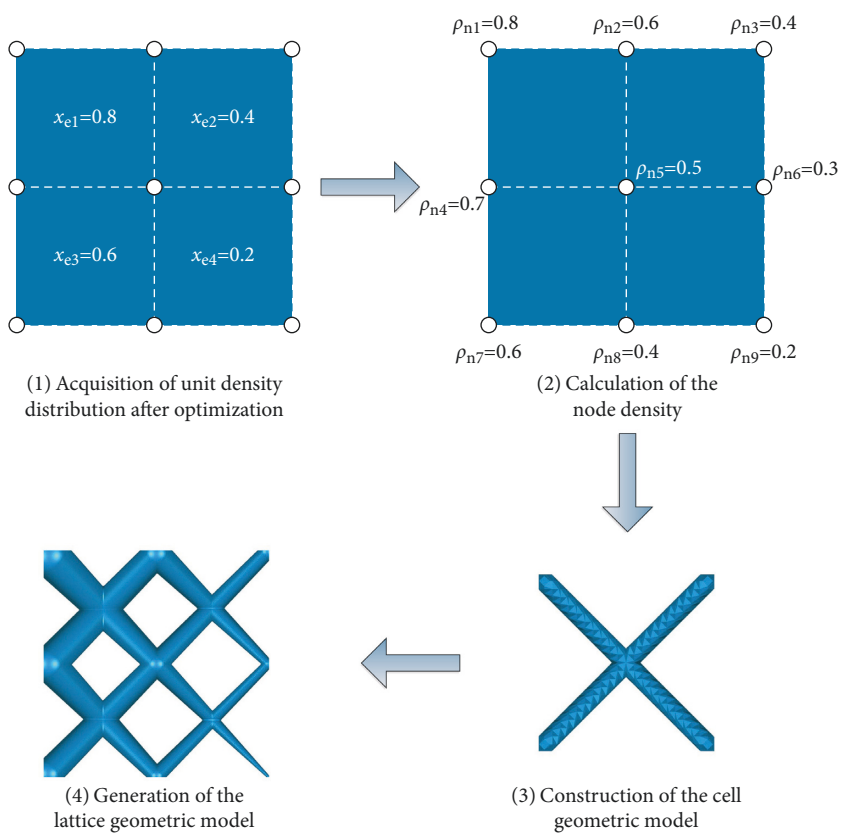

Figure 3: Schematic diagram of the variable-density lattice model.

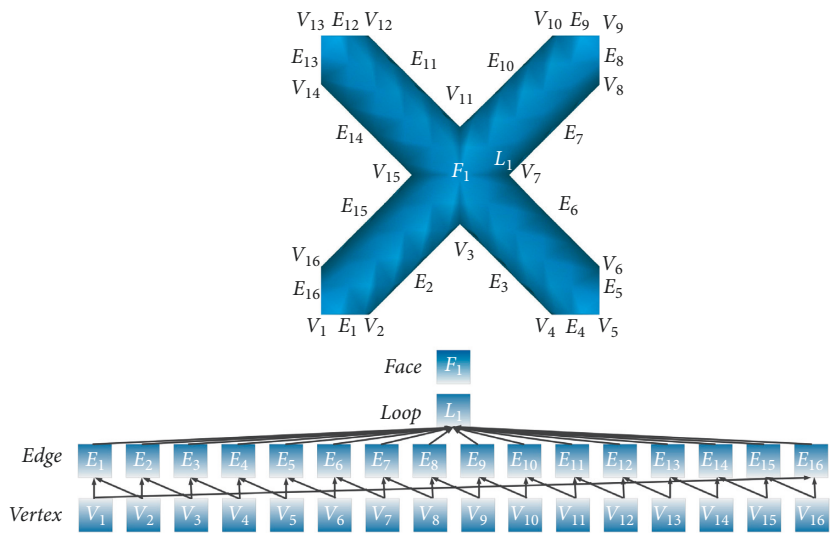

Figure 4: Schematic diagram of the B-Rep expression in the X-shaped cell.

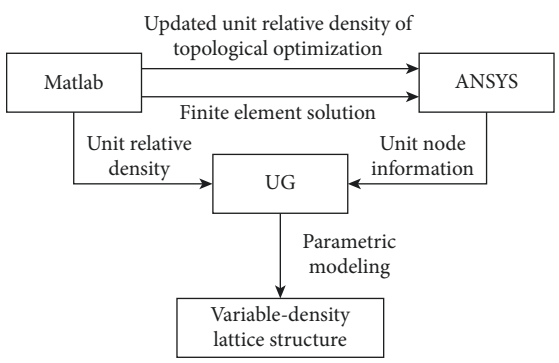

Figure 5: Basic flowchart.

and other information are produced after interactive MATLAB and ANSYS calculation. Finally, the relative density is used to construct a one-to-one connection between the element and the lattice structure cell. Thus, the variable-density lattice structure is parameterized and generated based on the element node information.

3. Parametric Modelling of Femoral Prosthesis

The ilium and femur of participants were scanned using CT for the model used in this experiment. The elastic modulus distribution in the appropriate region can be determined using the corresponding relationship equation, which can be reflected in the CT data. In the human body, the density of blood is approximately equal to that of water, which is $\rho_{\text{water}} = 1.0\,\text{g/cm}^3$, the corresponding apparent density is $\rho_{\text{APP\_0}} = 0$, and gray value is 0. The bone density in the area with the largest bone density is ρ_{cort}, and the gray value is 1613. Given that the hardest compact bone contains almost no liquid, its apparent density can be considered equal to the actual density. Therefore, the linear relationship between its apparent density ρ_{APP} and gray value H_{t} is as follows:

$$\rho_{\text{APP}} = \frac{H_{\text{t}}\rho_{\text{cort}}}{1613}. \tag{12}$$

The cortical bone is greatly different from the cancellous bone in density. The mapping relation of the elastic moduli could be expressed as piece-wise functions as follows:

Cortical bone:

$$\begin{aligned} E_{\text{Cortical}} &= 15010\rho_{\text{APP}}^{2.18}\nu \\ &= 0.3\rho_{\text{APP}} > 0.28. \end{aligned} \tag{13}$$

Cancellous bone:

$$\begin{aligned} E_{\text{Cancellous}} &= 6850\rho_{\text{APP}}^{1.49}\nu \\ &= 0.3\rho_{\text{APP}} \leq 0.28, \end{aligned} \tag{14}$$

where, E_{Cortical} and $E_{\text{Cancellous}}$ refer to the elastic moduli of the cortical and cancellous bones, respectively, and ν represents Poisson's ratio. (11) and (12) are utilised to get the distribution of elastic moduli in the femur, which is then used as the foundation for further microstructure design, modelling, and simulation experiments.

The neck plane of the femur (T_{20}), lesser trochanter plane of femur (T_0), and isthmus plane of femur (T_{N}) at the top of the femur's CT image is shown in Figure 6. These planes could reflect the data of the patient's femur and are suitable for designing prosthesis. The long and short diameters of the pulp cavity for different sections are measured and obtained on the abovementioned three planes and are recorded as L_{L20}, L_{B20}, L_{L0}, L_{B0}, L_{LN}, and L_{BN}. The distance from the neck plane of femur T_{20} to the isthmus plane of femur T_{N} is measured and recorded as L. The frontal projection data of CT data is used to pick CT data that might convey the morphology of the femur for the basis of individualised modelling. A section perpendicular to the center line of the neck of the femur is established at the intersection between the facial femur T_{20} and pulp cavity. The distance from the vertical point to center of the femur's head is

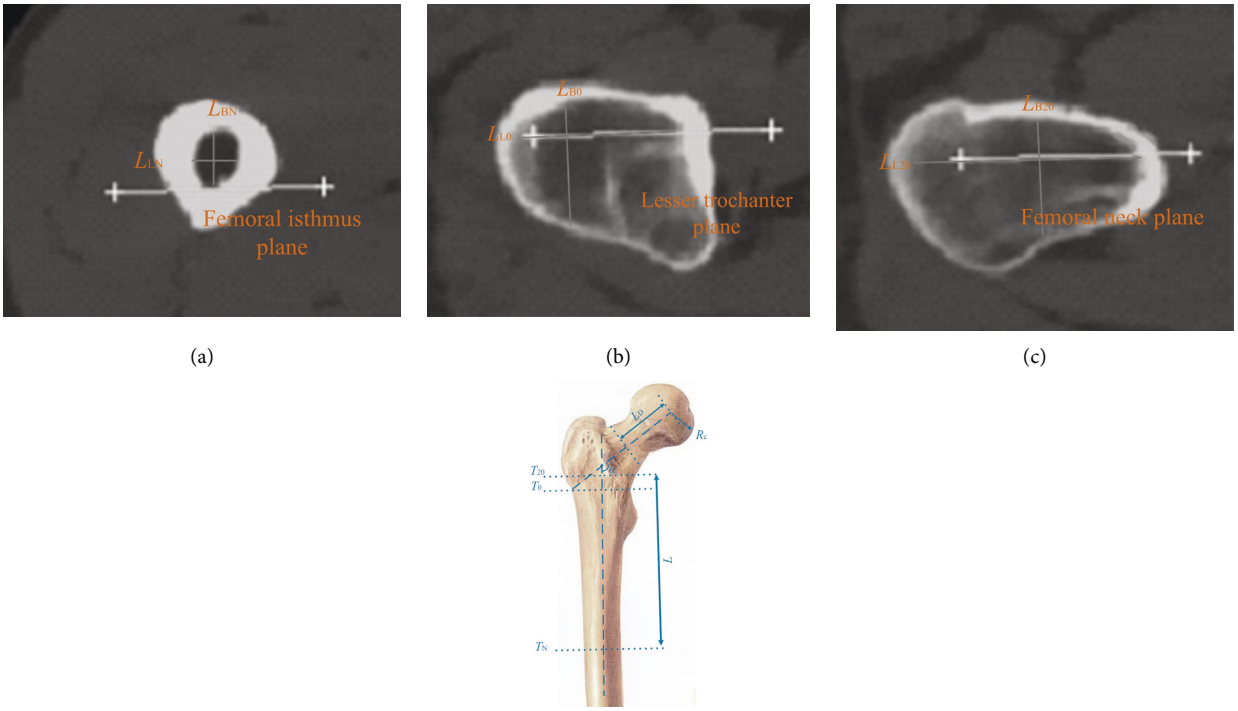

Figure 6: Extraction of the feature parameters of the femoral microstructure: (a) $\mathbf{T_N}$ face; (b) $\mathbf{T}_0$ face; (c) $\mathbf{T}_{20}$ face; (d) axial size of the femur.

measured and recorded as L_D. The angle between the central line of the neck and the central line of pulp cavity is measured and recorded as α. The radius of the head of femur is measured and recorded as R_c. For the prosthetic design, this data would serve as the primary reference sizes.

The parametric modelling system of the femoral prosthesis is built based on the open-cascade open-source modelling platform in this work to better adapt the prosthesis shape of the femur. The parametric modelling of the prosthesis is accomplished utilising the software based on the structural characteristics of the femur measured. Simultaneously, CT scans are utilised to simulate the ilium and femur in contact with the femoral prosthesis in order to verify and investigate the stress on the femoral prosthesis. Figure 7 depicts the completed model.

4. Results and Analysis

The results and analysis of the proposed work consist of the following parts:

4.1. Mechanical Model Establishment. In this experiment, the weight delivered to the femur is the same as when a human walks normally. The peak approach is used to model the walking process of an 80 kg human, which is broken down into three distinct moments: early (toe off), middle (single-leg support), and late (heel striking). In each typical instant, a load is applied, as shown in Tables 2, 3, and 4, correspondingly. A person's average walking pace is 4 km/h, with a maximum peak value of 3.8 times their body weight. Additionally, complicated miscellaneous loads with many functions are delivered to the upper femur during this phase, which are summarised in this experiment as joint force, abductor force, lateral femur muscle strength, and iliopsoas muscle strength. Figure 8 illustrates the loading technique.

4.2. Optimization Analysis. The femoral prosthesis is analyzed using finite element analysis. Then, the prosthesis is optimized topologically by using the topological optimization model of the multiscale variable-density lattice structure based on the homogenization method. The prosthetic material selected is Ti-6Al-4V alloy, with elastic modulus of 110 gigapascals (GPa), Poisson's rate of 0.3, and density of 4.5×10^{-6} kg/mm^3.

The load is delivered to the node in this experiment, and the force on the femoral prosthesis is uniformly distributed to the place where the femur is positioned. Changing the node location subject to the load adjusts the position of the load in the prosthesis. There are a lot of burdens to deal with. The computation must converge once the load is applied, which necessitates the creation of three analytical phases. The peak load on the top of the femur in the early stages of walking is applied in the load module in the first analytical phase, as indicated in Table 2. The peak load at the middle stage of walking is applied in second analysis as shown in Table 3. The load on the upper part of the femoral prosthesis in the late stage of walking is applied in the third analytical step as shown in Table 4. At the same time, fixed constraints are applied to the lower part of the parametric model of the upper femur.

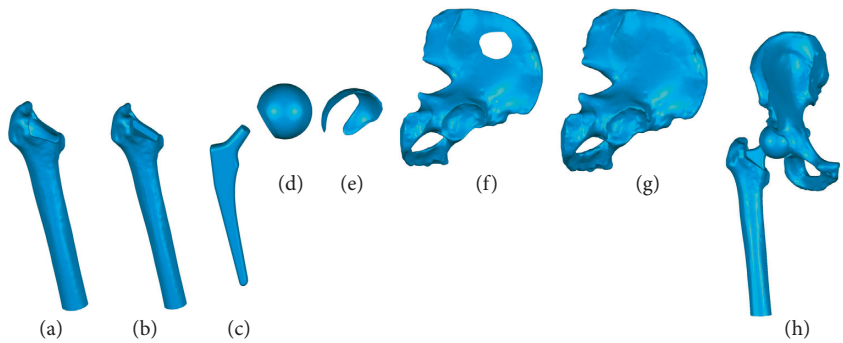

Figure 7: An example of the parametric modelling: (a) cortical bone of the femur; (b) cancellous bone of the femur; (c) femoral stem prosthesis; (d) femoral head prosthesis; (e) acetabular cartilage; (f) cancellous bone of ilium; (g) cortical bone of ilium; (h) assembled model.

Table 2: Joint force and muscle strength on the upper femur during walking at the early stage.

Direction	Joint force (N)	Abductor force (N)	Lateral femur muscle strength (N)	Iliopsoas muscle strength (N)
X	1160	−504	0	−17.6
Y	336	0	0	−131.2
Z	2800	−1352	1400	−123.2

Table 3: Joint force and muscle strength on the upper femur during walking at the middle stage.

Direction	Joint force (N)	Abductor force (N)	Lateral femur muscle strength (N)	Iliopsoas muscle strength (N)
X	290	−504	0	−17.6
Y	80	0	0	−131.2
Z	700	−1352	1120	−123.2

Table 4: Joint force and muscle strength on the upper femur during walking at the late stage.

Direction	Joint force (N)	Abductor force (N)	Lateral femur muscle strength (N)	Iliopsoas muscle strength (N)
X	290	−100	0	−88
Y	80	0	0	−565
Z	700	−254	700	−616

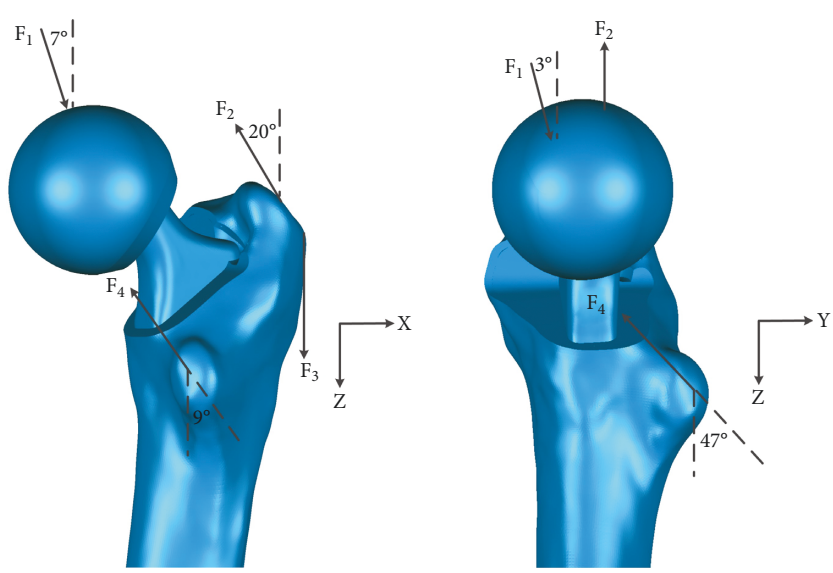

Figure 8: loading of the femur: $\mathbf{F}_1$ r, joint force; $\mathbf{F}_2$, abductor force; $\mathbf{F}_3$, lateral femur muscle strength; $\mathbf{F}_4$, iliopsoas muscle strength.

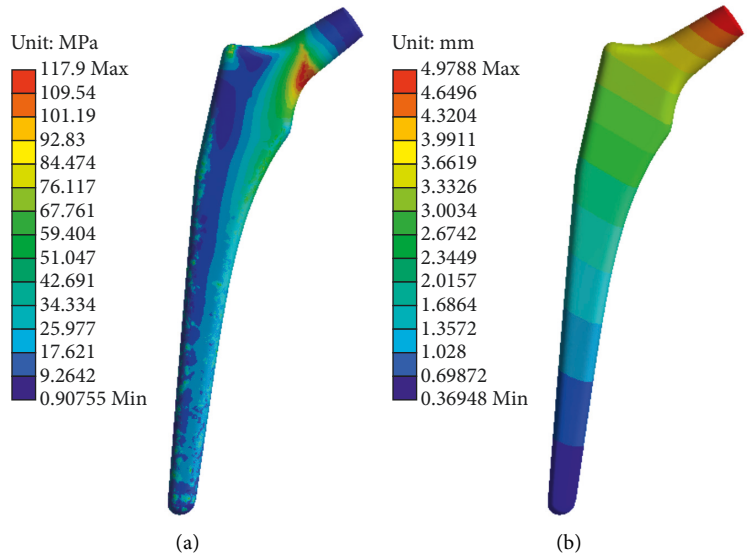

Figure 9: Numerical analysis of the all-metal femoral stem prosthesis: cloud charts of the (a) equivalent stress and (b) global deformation.

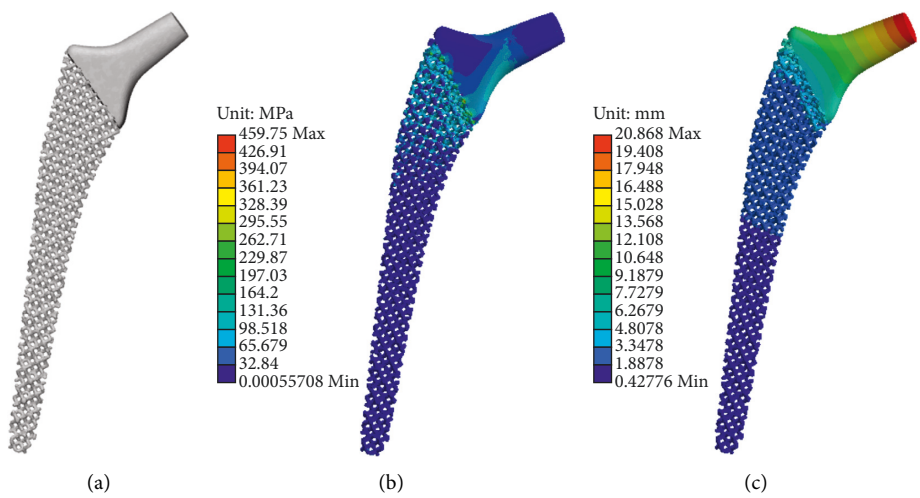

Figure 10: Numerical analysis of the uniform porous femoral prosthesis: (a) uniform prosthesis model and the cloud charts of the (b) equivalent stress, and (c) global deformation.

The prosthesis of the femoral head is the mainly stressed part, the whole solid structure is adopted. The optimization analysis of the femoral stem prosthesis is studied. After optimization, the finite element analysis is used to examine the complete solid femoral prosthesis model, uniform porous femoral prosthesis model, and the variable-density porous femoral prosthesis model. Figure 9 shows the analytical results of the global deformation and equivalent stress for all-metal femoral stem prosthesis. Figure 10 shows the uniform porous femoral prosthesis model (porosity, 50%) as well as analytical results of the global deformation and equivalent stress. Figure 11 shows the optimized variable-density porous femoral prosthesis model and the analytical results of the global deformation and equivalent stress.

As shown in Figure 9(a), the solid femoral stem prosthesis weighed approximately 151.9 g. The cloud chart of the equivalent stress showed a certain stress concentration at the neck of the femur, and the maximum stress is approximately 117.9 megapascal (MPa). The axial direction of the femoral prosthesis transmits the stress, while the stress on the lower surface is significant. This phenomenon is due to the fixed support constraint in this study. The cloud chart of the solid structure deformation is shown in Figure 9(b). The maximum deformation is located near the neck of the femur, and the maximum value is approximately 4.98 mm. The deformation gradually decreased towards the tail of the femoral stem prosthesis. The whole deformation tended to rotate around the tail of the prosthesis.

The uniform porous structure treatment is performed below the neck of the femur by using the rhombic dodecahedral element with porosity of 50% as shown in Figure 10(a) and weight of approximately 75.74 g, which is ~50.14% lower than the whole solid structure. The cloud chart of the equivalent stress as shown in Figure 10(b),

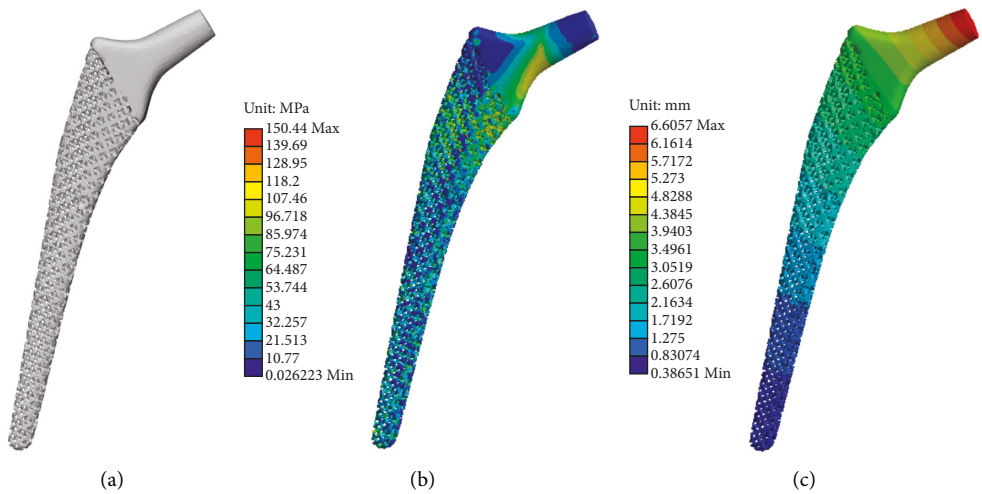

Figure 11: Numerical analysis of the variable-density porous femoral prosthesis: (a) variable-density prosthesis model and the cloud charts of the (b) equivalent stress and (c) global deformation.

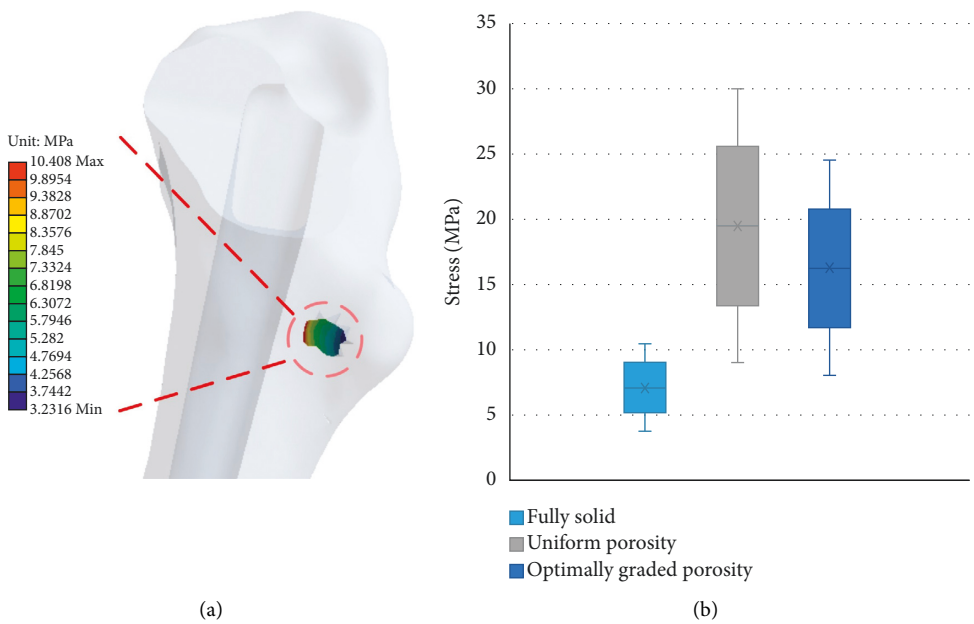

Figure 12: Featured regions of the femur: (a) regions prone to bone resorption and (b) stress distribution.

indicated a certain stress concentration at the neck of the femur and the transition between the solid and porous parts. The normal area of the load in the prosthesis decreased, and the stress increased accordingly. The maximum stress is approximately 459.75 MPa, considerably more than that of the whole solid femoral stem prosthesis. However, the stress concentration slightly improved. The stress concentration at the neck of the femur had slowed down, while the stress concentration at the lower end of the femoral prosthesis has significantly decreased. The cloud chart of the uniform density structure deformation is shown in Figure 10(c). With a maximum value of 20.87 mm, the largest distortion is seen around the femur's neck. The greatest deformation achieved by employing the porous structure is 4.19 times more than the total deformation of the solid structure. The distortion is mostly located above the femur's neck. From the transition between solid and porous portions to the tail, the deformation is minimal.

The femoral prosthesis is optimized topologically by using the topological optimization of multiscale variable-density lattice structure based on the homogenization method. The optimized femoral prosthesis structure is shown in Figure 11(a). The structure weighed ~87.23 g, which is ~42.57% lower than the whole solid structure material and ~15.17% more than the uniform porous structure material. The stress condition is shown in Figure 11(b). The cloud chart of the equivalent stress showed that the variable-density porous structure is similar to the whole solid structure. The maximum stress is ~150.44 MPa, which is ~27.6% more than that of the whole solid structure

and ~67.28% lower than that of uniform porous structure. The stress concentration is significantly improved, and the stress concentration in the neck of the femur is slightly slowed down. The cloud chart of the variable-density porous structure deformation is shown in Figure 11(c). Similarly, the maximum deformation is located near the neck of the femur, and the maximum value is ~6.61 mm. The variable-density porous structure is adopted. Its deformation is similar to that of the whole solid structure, which is ~32.73% more than the whole solid structure deformation and ~68.33% lower than that of uniform porous structure. The deformation gradually decreased towards the tail of the femoral stem prosthesis. The whole deformation tended to rotate around the tail of the prosthesis.

The region most prone to bone resorption in hip prosthesis replacement is shown in Figure 12. This study is performed to analyze the bone resorption in the feature region. To better evaluate the bone resorption, the stress shielding rate is used as a measurement of bone resorption. Stress shielding rate is calculated as follows:

$$\psi = \left(1 - \frac{\sigma_p}{\sigma_o}\right) \times \%, \tag{15}$$

where ψ refers to the stress shielding rate; σ_p refers to the stress after prosthesis implantation; and σ_o refers to the stress before prosthesis implantation.

The mean stresses in the highlighted region are 6.82, 19.49, and 16.25 MPa for the complete solid prosthesis, uniform porous prosthesis, and variable-density porous prosthesis, respectively. Figure 12 depicts the stress distributions in the feature areas of the three prostheses. When compared to a solid construction, the porous structure significantly improves stress shielding on the femur. The gravitational shielding caused by all-metal and porous stems differs significantly. This significant difference represented the fact that low-stretch implants are superior than high-stretch implants.

Topology optimization of the multiscale lattice structure proposed in this paper has achieved variable-density topological optimization. This approach produced not only an excellent lightweight effect, but also a superior stress distribution, demonstrating the lattice structure's capability and obviating the need for stress shielding.

5. Conclusion

This paper puts forward the topological optimization of a multiscale lattice structure based on the homogenization method. The following conclusions could be drawn: First, the homogenization approach is used to calculate and fit the function for calculating the equivalent mechanical performance of a cell. The results can speed up the computation and eliminate the need for the homogenization approach to be used many times. Second, a variable-density lattice structure design based on topological optimization is effectively implemented, leading to a novel lattice structure design idea. As a result, the characteristics of lattice materials are improved, resulting in even better results. Third, the proposed technology could well be employed in conjunction with 3D printing production. The technology can be used in a variety of sectors, including aerospace and tailored medical treatment, to produce small-batch high-performance lattice structures. The approach is also used to produce high-performance automotive lattice components, reducing the research and development cycle and saving money. Finally, the lattice structure had some special properties, such as high heat dissipation and high energy absorption. The proposed method can be further applied to heat dissipation, energy absorption, and other specific applications to realize the optimal design of high-performance lattice structures.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest for publication of this paper.

Acknowledgments

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Research Article

An Online Japanese Teaching Mode Based on Virtual Reality

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With the close cultural exchanges between China and Japan, the demand and quality of Japanese talents are gradually increasing. Traditional Japanese teaching modes and measures cannot meet the basic requirements. With the rapid development of network multimedia technology and virtual reality technology, in the process of Japanese teaching, virtual reality technology is used to reform the traditional teaching mode and to improve the quality of Japanese teaching. Based on virtual reality technology, this paper studies the online Japanese teaching mode, analyses the characteristics of Japanese teaching, combines modern information technology to assist teaching, comprehensively improves the quality of Japanese teaching, and improves the traditional Japanese teaching mode. By describing the concept, basic features, and components of the AR system in detail and by introducing the virtual construction method based on the geometric model, this paper improves the traditional Japanese teaching mode and establishes the online Japanese teaching mode. Finally, the online Japanese teaching mode for one semester is applied in colleges and universities to analyze whether this mode can improve students' interest in Japanese learning and the effect of Japanese learning. The results show that 59% of the students using this mode expressed an increased interest in Japanese learning, while only 25.8% of the students not using this mode showed an increased interest in Japanese learning. 72% of students indicated that they could improve their oral Japanese performance after using this model, while 45% of students who did not use this model could improve their oral Japanese performance.

1. Introduction

60% of Chinese and Japanese learners come from colleges and universities. Most of them focus on traditional teaching through research and analysis. The lack of interaction between Japanese teaching and students, the passive imparting of knowledge, the inability of students to interact with other classmates and teachers in the classroom teaching, the focus only on the teaching of basic Japanese skills, the lack of language ability, cross-cultural communication ability, and so on have made Japanese teaching in China stagnant [1]. For this phenomenon, this paper chooses virtual reality technology research and improvement of the Japanese teaching mode and constructs an online Japanese teaching mode [2].

This paper uses virtual reality technology in Japanese teaching, designs Japanese teaching courseware for sharing on the network, uses online dictionary to find Japanese vocabulary, uses professional websites to learn Japanese knowledge, establishes Japanese corpus, enriches Japanese teaching content, and establishes a new teaching mode and teaching evaluation system [3].

The main innovations in this research process are as follows. (1) First, the basic concepts and characteristics of virtual reality technology are introduced, the components of virtual reality system are listed, and the geometric model-based virtual modeling method used in this paper is described, and it is applied to the construction of online Japanese teaching mode. (2) Detailed description of the online Japanese development process, combined with virtual reality technology, using computer technology, virtual instruments, computer multimedia technology to build online Japanese teaching mode based on virtual reality technology [4].

2. Related Work

With the rapid development of modern education, Japanese teaching has begun to use virtual reality technology (VR) and multimedia technology; and on the basis of textbooks, virtual reality technology has been used to assist teaching [5]. Nowadays, as a new technology affecting the field of education, VR technology has a greater impact on teaching methods and teaching development and has also been concerned by a large number of scholars [6]. Kowalski proposed that virtual reality technology is the key to the future computer revolution. It can apply a more intuitive and natural behavior experience in teaching, making the traditional teaching mode and effect improve effectively [7]. Demitriadou et al. of the United States created the Virtual Reality Technology and Education Laboratory (VREL) to analyze whether virtual reality technology can be applied in the field of education to compare the effects of virtual reality teaching and other educational media applications and to analyze the impact of virtual reality technology on education [8]. Nuraliev proposed to enable learners to learn independently in a 3D virtual environment. Based on the selected autonomous actions and input language characteristics, the accuracy and complexity of language input are determined, that is, the real-time interaction between the learner and the virtual learning environment is maintained. The virtual environment can provide corresponding language input from the learner's action response and from various languages, which is called the interactive teaching with strong pertinence [9]. Yalagi et al. uses software in Japanese teaching, designs seven virtual learning tasks, deeply analyzes the students'execution status in the third task, finds problems in virtual teaching, and formulates improvement measures [10]. He points out the potential and future application of VR technology in language teaching. Ma Chongyu et al. constructed a distributed virtual environment platform for teaching and learning to form a three-dimensional virtual learning environment [11]. Li et al. analysed the application of virtual reality technology in China's education and described the virtual teaching project [12] developed by the cooperative relationship between Chinese universities and computer software companies. Chen et al. established a virtual classroom with unity 3D technology as the development environment and described in detail the ideas, technologies, and functions of designing the virtual environment [13]. Hu et al. comprehensively analysed the problems of using virtual reality technology in English teaching and described the successful cases, basic theories, and models of the application of virtual reality technology in English teaching, etc. [14]. Tian uses the GTL teaching mode in the oral Japanese teaching in colleges and universities to significantly improve the quality of oral Japanese teaching [15]. Liu applied mimetic teaching and etiology in oral Japanese teaching and applied this method to teaching time with ideal effect [16].

3. Overview of Virtual Reality Technology

3.1. Virtual Reality Technology. Virtual Reality (VR) technology is formed with the rapid development of computer technology. It integrates computer graphics, system simulation, and digital image processing. It is a comprehensive and strong subject. It belongs to simulation technology. It can integrate different sensory paths such as touch, vision, and hearing to create a three-dimensional environment. Users can use transmission devices to achieve real-time virtual and interaction in the virtual environment. The basic characteristics of virtual reality technology are listed in Table 1.

3.2. Virtual Reality System. The components of virtual reality system are headphones, HMD, data gloves, as well as information input and output devices, which use virtual software and environment to establish rule structure in virtual space, image, computer processing system, sound synthesizer, etc.

Figure 1 below is a component of a more widely used virtual reality system, which consists of a virtual environment generator, a virtual environment, users, sensor components, and action devices.

3.3. Virtual Modeling Method Based on Geometric Model. Virtual modeling technology based on the geometric model, that is, GBMR abstracts the real scene according to computer graphics, constructs a three-dimensional geometric model from polygons, such as buildings, terrain, and trees. Based on this, the lighting model in the virtual environment is constructed, the control parameters and texture mapping are set, and then the software is used to control the observer's lighting, position, and blanking information, and the real-time rendering output device completes the rendering of the visual picture and realizes the roaming of this scene, as shown in Figure 2 below, which is the basic flow chart of the geometric modeling method:

The three-dimensional graphic transformation represents a brand new three-dimensional graphics formed by the adjustment, displacement movement, and rotation of the three-dimensional graphics according to the same proportion. The geometric transformation in the three-dimensional graphics is completed by homogeneous coordinate transformation relative to the coordinate axis and coordinate origin.

3.3.1. 3D Translation Transformation. Move point $P(x, y, z)$ to point $P'(x', y', z')$ is as follows:

$$\begin{aligned} x' &= x + T_x, y' = y + T_y, z' = z + T_z, \\ T_x &= x' - x, T_y = y' - y, T_z = z' - z. \end{aligned} \tag{1}$$

The following matrix is obtained through translation transformation:

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ Tx & Ty & Tz & 1 \end{bmatrix}. \tag{2}$$

Table 1: Basic features of virtual reality technology.

Characteristics of virtual reality technology	Feature description
Immersion	When users are in a fixed situational experience, they can provide users with the most authentic feeling from the three aspects of hearing, vision, and touch, which can weaken the interference caused by external things and enhance users' attention.
Interaction	Information is transmitted between the system and users in two directions, and the system can give feedback in time according to the user's behavior to guide the user's next behavior when the user is in a special situation; on the contrary, user behavior has a direct impact on the later development of system programs, which can lead to the triggering of various events.
Imagination	Conceptuality is human imagination, which uses technology to simulate situations that do not exist or cannot exist in the real environment

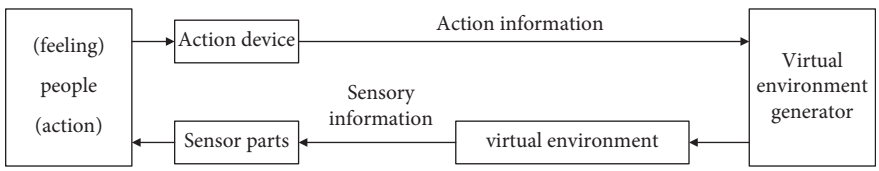

Figure 1: Virtual reality system.

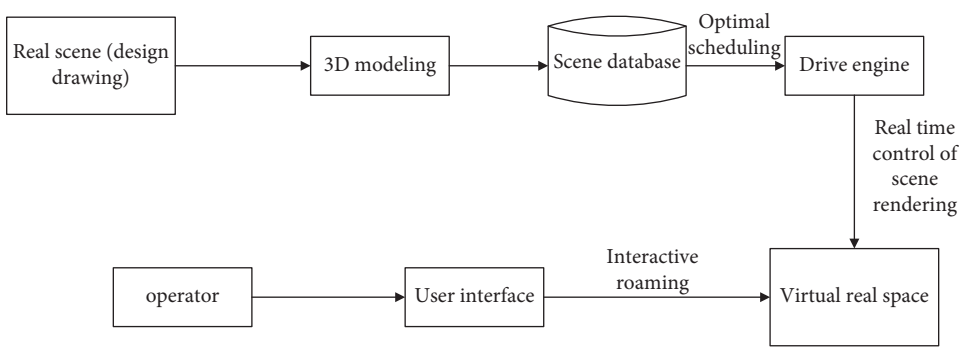

Figure 2: Flow chart of the geometric modeling method.

The following are the translation coordinate transformation of points:

$$[x' \ y' \ z' \ 1] = [x \ y \ z \ 1] \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ Tx & Ty & Tz & 1 \end{bmatrix} = [x \ y \ z \ 1]. \quad (3)$$

3.3.2. 3D Scale Transformation. If the coordinate transformation $P(x, y, z)$ is the vertical coordinate axis of the object center relative to the coordinate origin, set the transformation proportion as a, b, and c. If the three proportions are equal, the object needs to be transformed in real time and equal proportion. After transformation, the $P'(x', y', z')$ coordinate is obtained, and its transformation matrix is as follows:

$$T = \begin{bmatrix} a & 0 & 0 & 0 \\ 0 & b & 0 & 0 \\ 0 & 0 & c & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}. \quad (4)$$

The following is the calculation formula of point scale change coordinates:

$$[x' \ y' \ z' \ 1] = [x \ y \ z \ 1] \begin{bmatrix} a & 0 & 0 & 0 \\ 0 & b & 0 & 0 \\ 0 & 0 & c & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [x \ y \ z \ 1]T. \quad (5)$$

3.3.3. 3D Rotation Transformation. When the object rotates around the coordinate axis, the transformation point $P(x, y, z)$ will be $P'(x', y', z')$. The corresponding P' transformation matrix is also different due to different coordinate axes.

If point P rotates around the X axis, the following transformation is obtained:

$$x' = x, y' = y \cos \partial - z \sin \partial, z' = y \sin \partial + z \cos \partial. \quad (6)$$

The following transformation matrix is obtained:

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & con\,\partial & \sin \partial & 0 \\ 0 & -\sin \partial & con\,\partial & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}. \quad (7)$$

After the transformation of point P with the X axis as the center, the following coordinate transformation is obtained

$$[x'\ y'\ z'\ 1] = [x\ y\ z\ 1] \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & con\,\partial & \sin \partial & 0 \\ 0 & -\sin \partial & con\,\partial & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [x\ y\ z\ 1]T. \quad (8)$$

After point P rotates around the Y axis, the following transformation formula is obtained

$$[x'\ y'\ z'\ 1] = [x\ y\ z\ 1] \begin{bmatrix} \mathrm{con}\partial & 0 & -\sin \partial & 0 \\ 0 & 1 & 0 & 0 \\ \sin \partial & 0 & \mathrm{con}\partial & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [x\ y\ z\ 1]T. \quad (9)$$

The following coordinate transformation formula is obtained during the rotation of point P with the Z axis as the center

$$[x'\ y'\ z'\ 1] = [x\ y\ z\ 1] \begin{bmatrix} \mathrm{con}\partial & 0 & -\sin \partial & 0 \\ 0 & 1 & 0 & 0 \\ \sin \partial & 0 & \mathrm{con}\partial & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [x\ y\ z\ 1]T, \quad (10)$$

where ∂ represents the rotation angle centered on the P axis.

4. Online Japanese Teaching Mode

4.1. Development of Japanese Teaching. The development stage of Japanese teaching focuses on resources and means. The use of computers can improve teachers' correcting homework methods and lesson preparation modes. The use of computer multimedia technology in learning methods can also be adjusted to help teachers teach and change students' learning methods. Virtual reality technology provides Japanese teachers and students with a large number of Japanese resources, and the network provides them with a platform for communication and learning. The development process of Japanese teaching is listed in Figure 3.

According to the development process of Japanese teaching shown in Figure 3 above, the research on online Japanese teaching mode in China is still in its infancy. Teachers regard online teaching as a way to supplement traditional teaching in Japanese teaching. Japanese teaching and online teaching are not dominant in the process, and the main position of Japanese online teaching is not involved. Compared with English online teaching, Chinese teaching, and online English teaching, Japanese teaching mode is relatively backward [17].

4.2. Japanese Online Learning Mode. Online teaching can also be called e-learning. It is a new teaching mode formed under the rapid development of Internet technology, which is used to supplement and extend the traditional classroom teaching [18]. Online Japanese teaching based on virtual reality technology can obtain a large number of online education resources, and students can realize independent teaching, so as to break the disadvantages of Japanese online learning and enable students to obtain Japanese teaching resources at any time [19]. The following are the basic forms of Japanese online teaching.

(1) Share Japanese teaching courseware on the network. Japanese teaching teachers upload personal Japanese teaching materials, teaching contents, teaching courseware, etc. to the cyberspace, which mainly includes interactive learning communities, shared spaces, personal blogs, and QQ groups. In the process of learning Japanese, students preview and review the teaching content from their personal needs. This form is to supplement the Japanese classroom teaching.

(2) Online dictionary. One of the main tools in foreign language teaching is dictionaries. Nowadays, the rapid development of network technology has strengthened the professionalism of dictionaries. Students can access online dictionary software by using the network, such as primary school library dictionary, Google translation, and Baidu translation. With the rapid development of network technology and virtual reality technology, software developers have launched an online Japanese Teaching Dictionary applied on the mobile client. Users can access the contents of the Japanese dictionary after downloading the client on the mobile phone.

(3) Professional website. At present, common learning websites include Japanese learning blogs and Chinese websites for Japanese learning. These websites regularly upload materials such as Japanese introductory courses, Japanese examination contents, Japanese practical sentences, business English, or online courses and also provide students with a virtual interactive area for communication and communication between students.

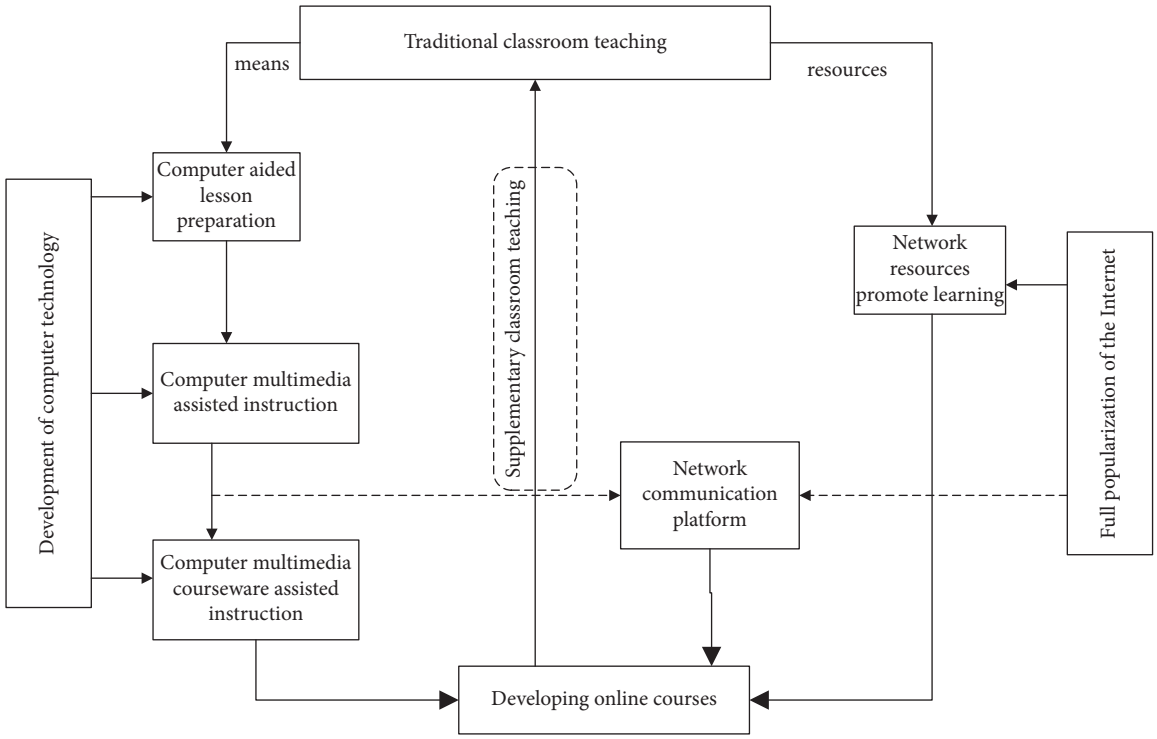

Figure 3: Development process of Japanese teaching.

(4) Online broadcast. Students can use online radio to practice personal listening, including TBS and NH.

(5) Corpus. The knowledge base required for learning Japanese is corpus, which contains various professional resources required for learning Japanese. Users can download and use the corpus free of charge.

4.3. Japanese Online Teaching Mode. This paper draws lessons from the traditional Japanese teaching mode based on the combination of teaching practice and virtual reality technology, deeply analyzes the characteristics of Japanese Teaching in Colleges and universities, and summarizes various teaching modes suitable for Japanese online teaching, as shown in Figure 4.

Based on virtual reality technology, this paper studies the online Japanese teaching process from the perspectives of teachers and students. The teaching inquiry stage belongs to the early preparation process of teachers, and the teacher preparation stage involves teaching analysis, inquiry preparation, and problem description [20]. The teacher analysis stage mainly includes analysis of learning tasks, analysis of learning characteristics, feasibility analysis of solving problems, and analysis of three-dimensional teaching objectives. The inquiry preparation process is the basis for students' learning, including the required learning tools, platforms, and courseware. Students' inquiry learning is to complete inquiry activities in a certain area designated by the classroom. The classroom sets the problems to be studied and briefly analyzes the inquiry theme before students' initial inquiry.

Students complete learning activities in the virtual environment, first get familiar with and practice the teaching instruments and virtual instruments used in online Japanese teaching, then complete Japanese teaching exploration, communicate with peers after teaching, and then analyze and reflect on the exploration process. After that, teachers conduct self-evaluation and evaluate students' learning situation. Teachers realize the design of online Japanese teaching mode according to students' learning status.

5. Result Analysis of Online Japanese Teaching Mode Based on Virtual Reality Technology

5.1. Analysis on the Influence of Online Japanese Teaching Mode on Students' Interest. This paper studies the online Japanese teaching mode based on virtual reality technology and constructs an online Japanese teaching mode suitable for students. By applying this mode to college teaching, this paper analyzes and tests the effect of the actual Japanese teaching mode. This paper analyzes the impact of online Japanese teaching mode on students' learning interest. Interest is the main driving source for students to learn Japanese. Therefore, only after improving students' interest can students mobilize their motivation to participate in teaching activities and change students' previous passive learning mode to active learning. It can be seen that interest is the key to improve students' oral Japanese ability. Based on the virtual reality online Japanese teaching mode, this paper completes the design of teaching activities and teaching resources from students' preferences and actual needs so as to obtain students' interest in Japanese learning.

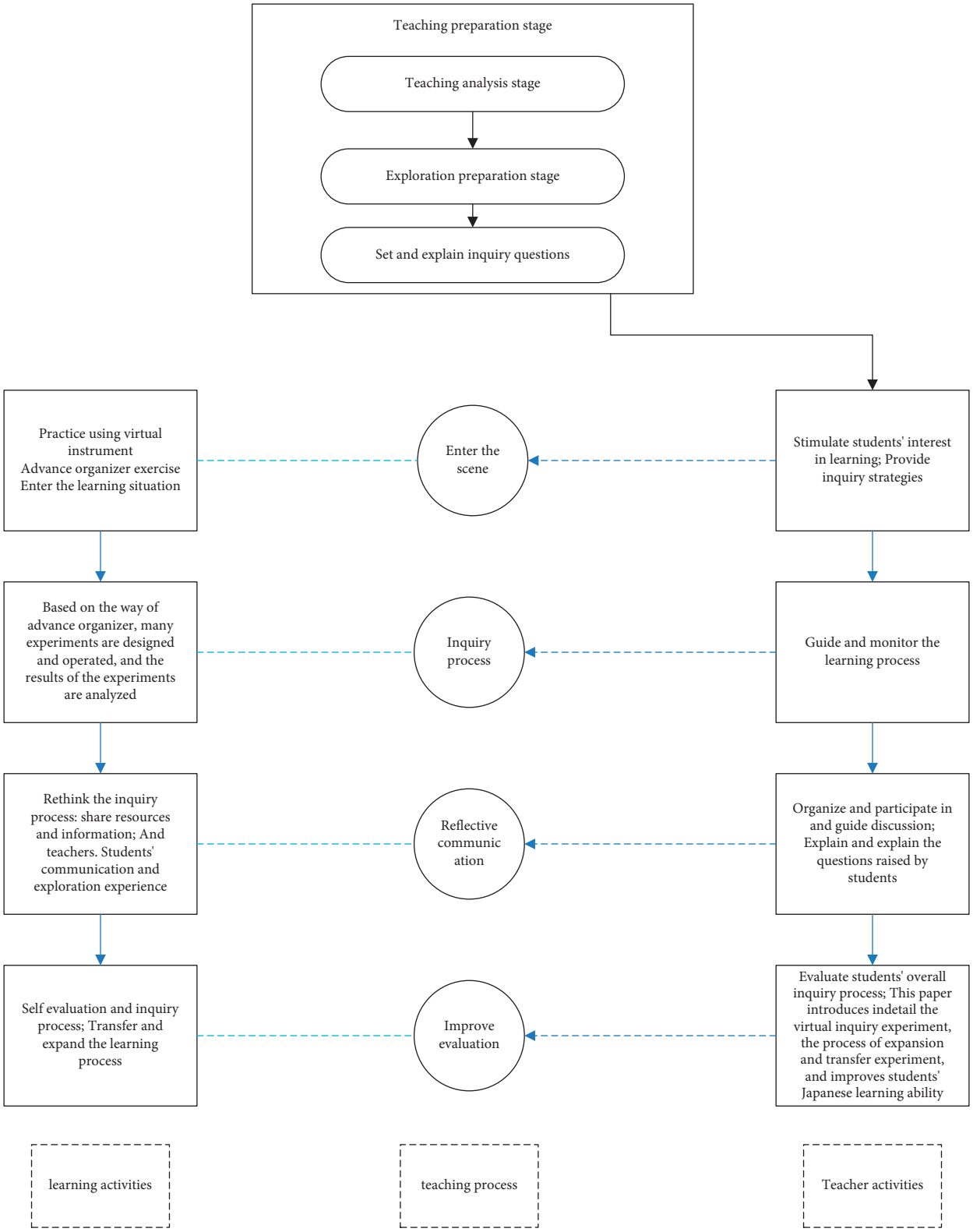

Figure 4: Online Japanese teaching mode based on virtual reality technology.

Through the investigation of students' interest in oral Japanese learning, this paper is divided into five different levels for the problem of "degree of interest in oral Japanese courses." Among them, the students in the experimental group use the online Japanese teaching mode based on virtual reality technology, and the students in the control group use the traditional Japanese teaching mode. The analysis of students' interest in learning Japanese by the two

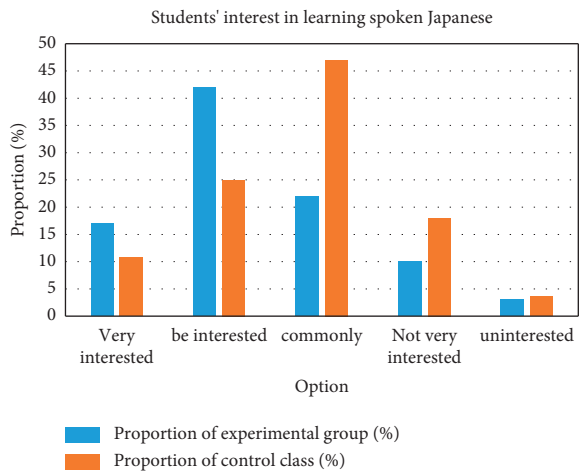

Figure 5: Students' interest in learning spoken Japanese.

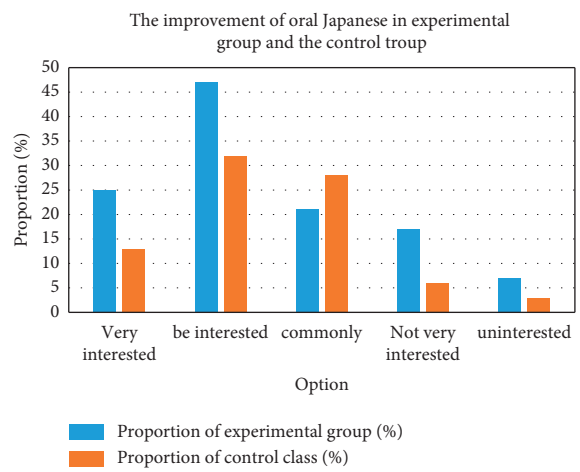

Figure 6: Improvement of oral Japanese in the experimental group and the control group.

different teaching modes is compared and analyzed, as shown in Figure 5.

According to the data in Figure 5 above, 17% of the students in the experimental class are very interested in learning Japanese, and 10.8% of the students in the control class are very interested in learning Japanese. 42% and 25% of the experimental class and the control class are interested in learning Japanese, respectively, and 22% and 47% of the experimental class and the control class are generally interested in learning Japanese, respectively. Combined with the data, it shows that the students in the experimental group are generally more interested in learning Japanese than those in the control group, which fully shows that the online Japanese teaching effect of virtual reality technology in colleges and universities is remarkable and can improve students' interest in Japanese learning.

5.2. Analysis on the Influence of Japanese Learning Effect. After using the online Japanese teaching mode based on virtual reality technology in the actual Japanese teaching for one semester, the students' learning effect and oral Japanese performance were investigated and analyzed. The students in the experimental group used the Japanese teaching mode, while the students in the control group did not use the online Japanese teaching mode. Through comparative analysis, the effect of applying the online Japanese teaching mode was analyzed. The set question is "whether there is a great improvement in personal Japanese expression ability after one semester of Japanese teaching." Figure 6 shows the results of the experimental group and the control class.

Analyze the improvement of oral Japanese of students in the experimental group and the control group in Figure 6 above. The proportion of students in the experimental group and the control group who can greatly improve their oral expression ability is 25% and 13%, respectively, with a difference of 12%. 47% and 32% of the experimental group and the control group said that their oral English level had improved, respectively, and 21% and 28% of the experimental group and the control group said that their oral expression ability had not been significantly improved, respectively. According to the data, the oral expression of students in the experimental group is much higher than that in the control group, which fully shows that the online

Table 2: Oral Japanese achievement.

	Class	Number of cases	Average value	Standard deviation	Standard error mean
Interim results	Experimental class	30	69.75	16.5	3.1
Test results	Control class	28	64.8	17.7	3.4

Table 3: Independent sample test of students' oral Japanese performance in midterm.

		Variance equivalence test		Variance equivalence test					Variance equivalence test	
		F	Significance	t	Freedom	Sig	Average value	Standard error value	Difference 95% confidence interval	
									Lower limit	Upper limit
Interim results	Assuming equal variance	059	809	1042	57	0.14	4.7	4.5	4.29	13.7
	Assumed variance inequality			1039	54.9	0.14	4.7	4.51	4.33	13.8

Japanese teaching mode can significantly improve students' oral Japanese ability.

Then, sort out the oral Japanese test results of the experimental class and the control class twice, using SPSS 25.0 software to process the data and test the students' Japanese learning effect according to the performance of the experimental group and the control group. Table 2 shows how to use SPSS 25.0 software statistical analysis of the results of oral Japanese test in the experimental class and the control class.

In Table 2 above, the average Japanese oral performance of the test experimental class is 69.75, and the average Japanese oral performance of the test control group is 64.8. Compared with the experimental class, the oral performance of the two classes is higher. Further, independent sample t-test analyzed the performance of the two groups of students, and the results are shown in Table 3 below.

Table 3 shows the test results of this sample t, and the t distribution value and significance are 1.5%, respectively, 042 and 0.013, indicating that the oral Japanese test scores in the experimental class and the control class are significant. After one semester of online Japanese teaching, the oral Japanese level of the experimental class is much higher than that of the control class, and its performance is also higher, which fully proves that this teaching mode can improve the students' oral Japanese performance and quality.

Compared with the traditional Japanese teaching mode, this paper uses the online Japanese teaching mode based on virtual reality technology, which has strong flexibility in teaching design. Completing the teaching design according to students' interest can better stimulate students' interest in learning Japanese and improve students' initiative and enthusiasm in learning Japanese. The teaching form is highly comprehensive. Combined with the online and offline teaching mode, it guides students' learning attitude and learning mode and constructs a self-management and adjustment mechanism to make students have a good habit of learning Japanese.

6. Conclusions

The traditional Japanese teaching mode focuses on classroom teaching, and teachers play a leading role in the teaching process. In the classroom, teachers analyze the Japanese text for students. However, this Japanese teaching mode cannot make students integrate into the Japanese situation, and it is difficult to feel the fun of Japanese learning. Students' learning and teachers' teaching process are boring, which makes students lose interest in Japanese learning. Students are unable to play their main role during their study, resulting in an unsatisfactory learning effect. At the same time, the trade between China and Japan has been close in recent years, which requires a large number of Japanese talents. The students trained by this teaching mode are not competent for the job requirements. Therefore, it is urgent to reform the traditional Japanese teaching mode, use new teaching methods to improve teaching quality, and strengthen students' oral teaching. Therefore, this paper uses virtual reality technology to study the online Japanese teaching mode, uses the most advanced multimedia teaching, deeply excavates Japanese teaching resources, and uses computer and network for auxiliary teaching to construct the online Japanese teaching mode, which is widely used in colleges and universities. This paper analyzes from two aspects: Affecting students' interest in Japanese learning and affecting students' Japanese learning effect. The experimental group and the control group are set for comparative analysis. The results show that the scores of students in the experimental group are higher than those in the control group.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Effectiveness of Computer-Aided Technology for Teaching English Courses in the Internet Era

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Computer and Internet technologies have advanced significantly in recent years. They have been incorporated into people's daily lives and workplaces. The traditional English teaching approach has several problems. It includes poor student learning interest and lack of active learning. English teaching courses are set up in colleges and universities for non-English majors. The contradiction between students' needs for foreign language learning and personal interests is increasing day by day. Traditional single classroom teaching has been unable to meet the basic requirements. With the rapid advancement of Internet technology, computer-aided technology is being proposed and applied in English education to investigate the effectiveness of English instruction. This article goes into detail on the idea, classification structure, and courseware design process of computer-aided technology. It employs the AI teaching approach in English instruction, creates a similarity matrix of English learners, and assesses English learners who exhibit similar behavior. Finally, the students are tested by answering the proportion of 1000 words correctly in English teaching to measure the effect of course learning. The results show that the number of words memorized by students increases after using computer-aided technology. This article analyzes students' capacity to compose in English and evaluates the efficacy of students' English teaching. It proclaims that after teachers adopt computer-aided technology, the error rate in English composition is reduced. The total score in English increased from 58.6% to 69.6%.

1. Introduction

Education technologists have long lauded computer technology's promise to transform university teaching and learning. Academic journals in educational technology publish research on the capabilities of technologies such as computers and the Internet to speed university students' learning, improve and democratize access to educational opportunities, and promote interactivity, engagement, and collaboration. In short, it is thought that the shift toward computer-based teaching and learning during the last 20 years has changed and reinvigorated the university sector. Thus, education technologists continue to issue stern ultimatums that colleges must either "change or die" in the face of technological innovation.

This unwavering trust in higher education's "technological remedy" is evident in the billions of dollars poured into education each year worldwide. Besides technology-enabled distance education, much of this money is now being spent on on-campus applications. Indeed, institutional spending on computer infrastructure has risen considerably during the previous decade. With the increasing usage of virtual learning environments such as WebCT, Blackboard, and Moodle, the notion of the university campus has shifted from a bricks-and-mortar to a clicks-and-mortar model. Computer technology has become a symbol of early twentieth century higher education provision in developed and developing nations.

Computer-aided technology (CAI) is a type of teaching-aided technology that has emerged because of the fast advancement of computer technology. Its essence is to conduct teaching activities using computers as a teaching medium, and teachers utilize computers to fulfill aided teaching tasks [1]. It thoroughly explains computer-aided technology, covers fundamental principles, and explains categorization of frameworks and courseware design. It serves as a vital

theoretical foundation for researching the efficiency of computer-aided technology in English teaching [2]. The advantage of computer-aided technology lies in its strong interaction, integration, and diversity. Interaction is used to distinguish the teaching methods of the one-way output such as TV, multimedia technology, and film. It combines graphics, animation, sound, and video into the teaching content and exhibits the course information with both voice and emotion so that teachers may better complete English teaching and increase the quality and effectiveness of English teaching.

CAI can exhibit the teaching content flexibly and thoroughly through the computer. It better regulates the teaching process and eventually achieves the teaching goal while effectively improving the teaching quality, efficiency, and level. To evaluate the efficiency of English course teaching, two classes of students are chosen to take a writing test during the first week of school and after the semester, which must be finished in 45 minutes. When analyzing the effect of computer-aided technical English teaching, this paper tests and feeds back 42 words by using the computer and counts the results. The number of words in this test is 42, with wrong and correct answers. The wrong words will be displayed on the computer page, and then, the corresponding Chinese meanings of these words will be listed. According to the experimental results, it is fully demonstrated that the experimental class's total English score and translation ability improved significantly after using computer-aided technology. However, the score of the control group without computer-aided technology did not improve significantly. It demonstrates that the effect of computer-aided technology in English teaching is ideal.

Presently, CAI technology is widely used in college teaching, but various disciplines have significant differences. Most CAI technology is used in the teaching of technical disciplines as well as in English course teaching. It is efficient in both technical and nontechnical disciplines. The traditional English course teaching model lacks flexibility. It slavishly follows the bookish rule of constructing structures as prescribed by the grammarians. The students' classroom environment is not lively, it is difficult to pique kids' interest in learning, and it is difficult to give a better English language setting. Facing these problems, computer-aided technology has been introduced to study the effectiveness of English teaching and improve the quality of English teaching.

The innovations of this paper are as follows:

(1) This research investigates the usefulness of computer-assisted technology in English instruction in the Internet era. Computer-aided technology is applied in English course teaching to study the effectiveness of English teaching.

(2) The AI technology of computer-aided technology to be used in English course teaching is selected, the similarity matrix of English learners is constructed, the English recommendation threshold is set, and the English teaching system of computer-aided technology is established.

After the introduction section, the work related to the study has been discussed. Following that, the computer-aided technology under the background of the Internet has been explained. After that, the application of computer-aided technology using the Internet has been discussed. Lastly, the analysis of English teaching and the conclusion of the research paper have been discussed.

2. Related Work

After years of development, computer-aided technology has become increasingly mature. Now it is widely used in the field of teaching, which has attracted the attention and research of scholars at home and abroad. Gao developed computer-aided Chinese teaching, designed, developed, and made full use of teaching resources for evaluation and management in a multimedia environment, compiled and designed multimedia teaching materials, and developed and used multimedia Chinese courseware [3]. Liu and Hungpointed out that the use of computer-aided teaching of Chinese as a foreign language can activate the Chinese classroom form, improve the classroom efficiency, highlight students' comprehensive skills and memory, and has significant advantages compared with the traditional teaching mode [4]. Christel analyzed the impact of computers on media technology in teaching Chinese as a foreign language from the perspective of teaching methods, teaching contents, and teaching organization forms [5]. Mayer proposed that the use of multimedia technology in English teaching provides a new way of teaching, which is convenient to strengthen students' learning intuition, and the learning effect is ideal [6]. Gunawardhana's research points out that CAI can solve the problems of teaching space and time. Students can review and learn the course content anywhere by using the network and can fully popularize the teaching methods [7]. Marlowe and Tsilomelekis proposed that foreign language teaching policies, economic development, teachers' learning experience, and their own abilities all affect the effect of English teaching. After using computer-aided teaching, teachers can analyze teachers teaching behavior in any situation and change teachers' teaching methods [8]. Nagata's research points out that various factors such as classroom, students, and environment will affect teachers' CAI methods. Because teachers need to design courseware and select videos and images when using CAI, teachers' ability directly determines the effect of CAI [9]. Ai et al. pointed out that when studying the effectiveness of computer-aided technology in English teaching, we can judge from many aspects such as teaching objectives, teaching quality, and teaching effect so as to avoid selecting a single direction for evaluation, and the real effective results of English teaching cannot be obtained [10]. Ji believes in the effective framework of CAI and summarized several factors affecting the teaching effect, such as teaching methods, teaching design, and students' interests [11]. Kara studied the skills and CAI attitude of visual art teachers from the perspective of school factors and demographics and comprehensively investigated the personal attitude of students toward the use of CAI. The results showed that the candidates of visual teachers recognized the effect of CAI [12].

3. Computer-Aided Technology under the Background of the Internet

Computer-aided technologies are the use of computer technology to aid in the design, analysis, and manufacture of products. The ever-increasing spread of the use of the Internet in intelligence technologies has begun to revolutionize people's life. This section explains the concept of computer-aided technology and the classification framework of the study.

3.1. Computer-Aided Instruction Concept. Presently, the most widely used teaching technology is computer-aided technology. Computer-aided teaching uses computers as the teaching medium to complete teaching activities. During teaching, teachers use computers to design teaching courseware, enrich teaching contents by means of numbers, words, and images, and display teaching videos, teaching images, teaching sound, and animation so as to realize multidimensional and three-dimensional communication of educational information and strengthen the expressiveness and authenticity of information [13]. In addition, students use input and output devices to realize human-computer dialogue on the computer. This human-computer interaction is a significant feature of computer media, while other teaching methods such as TV and slide show do not have this function [14].

When using computer-aided technology in teaching, we can stimulate students' senses from many aspects and let students obtain knowledge and information from all aspects. From the perspective of psychology, people can acquire about 15% of their knowledge in hearing and about 25% knowledge in vision. If these two methods are used in teaching to transfer knowledge, at the same time, their acceptance is as high as 65%. The US survey data show that the use of computer-aided technology can improve about 38% compared with ordinary teaching methods and save about 31% of teaching time.

3.2. Classification Framework of CAI. The computer-assisted instruction model can be called an information-based teaching model. It studies the teaching model from the values and cognition and formulates the classification framework of computer-assisted instruction. From the perspective of cognitive theory, there are two opposing concepts, namely, constructivism, and objectivism. From the perspective of values, there are also two opposing concepts, namely, collectivism, and individualism. This paper uses the two-dimensional coordinate system to illustrate the differences between various types of education by selecting the four dimensions of collectivism, individualism, constructivism, and objectivism so as to obtain the classification framework of the computer-assisted instruction shown in Figure 1.

CAI is a comprehensive teaching mode formed by using modern teaching theory and modern teaching information technology in teaching. The key to this teaching style is to employ computer-based courseware and to fully utilize multiple technologies such as teaching design, teaching theory, computer-aided technology, and program design to complete courseware design, production, and usage. The CAI's effective framework was used to synthesize numerous factors affecting the teaching effect. The factors affecting the teaching techniques are teaching design and students' interests. The framework is shown in Figure 2.

Formally, CAI uses the computer as a teaching tool, which is more advanced than electrochemical teaching equipment and traditional teaching form. As a brand-new teaching technology, CAI can display the teaching content flexibly and comprehensively through the computer, better control the teaching process, and finally achieve the teaching goal and realize the effective improvement in the teaching quality, efficiency, and level.

4. Application of Computer-Aided Technology in English Teaching

Computer-assisted language instruction can significantly improve students' self-learning abilities. Teachers can employ a multimedia curriculum to personalize the standard way of the content to be taught in the context of computer-assisted language education. In this section, the applications of the technology have been discussed.

4.1. AI English Teaching. At present, the use of the AI computer-aided teaching method in English teaching can improve the English teaching environment, solve the problem of "deaf-mute English" in the past, and let students experience personalized teaching methods so as to optimize the teaching effect and make full use of English teaching resources. AI technology can be used in the computer to comprehensively analyze various media information technologies such as graphics, text, sound, and images, and an intelligent system is formed based on the data connection logic [15]. The remarkable advantage of this system is that it can provide different English teaching interaction modes, such as text interaction, content interaction, and graphical interface interaction. The three interaction modes are independent of each other and jointly strengthen the teaching effect [16]. AI teaching interaction mode is shown in Figure 3.

4.2. Constructing the Similarity Matrix of English Learners. Based on the characteristic vector T of learners' personalized information, assuming that T_1 (student number) is different and the number is n, this paper forms the characteristic matrix of $TZ_{n\times 30}$ personalized information, which is expressed by the following formula (1). There is a similarity matrix between any learner and learners with similar characteristics, which is represented by $u_{30\times n}$. The formula is as follows:

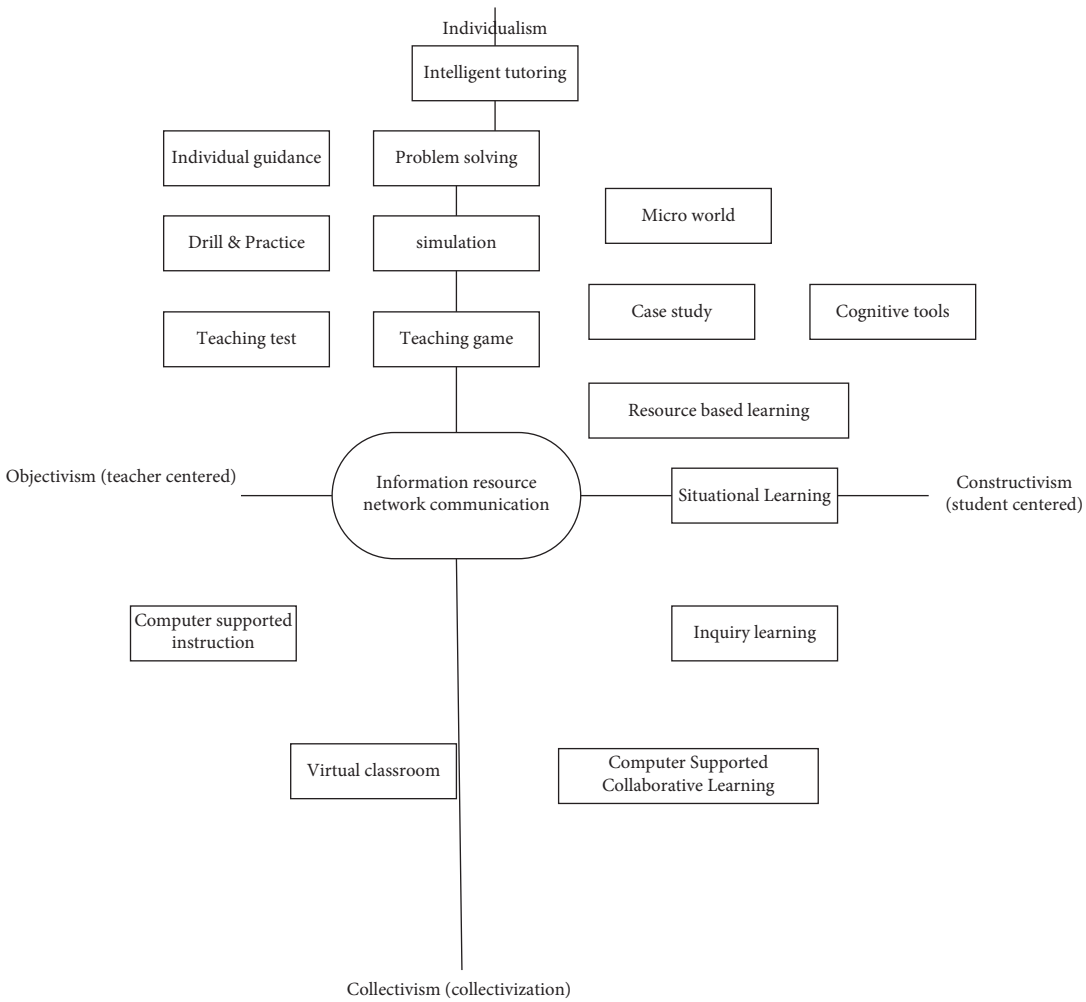

Figure 1: Classification framework of CAI.

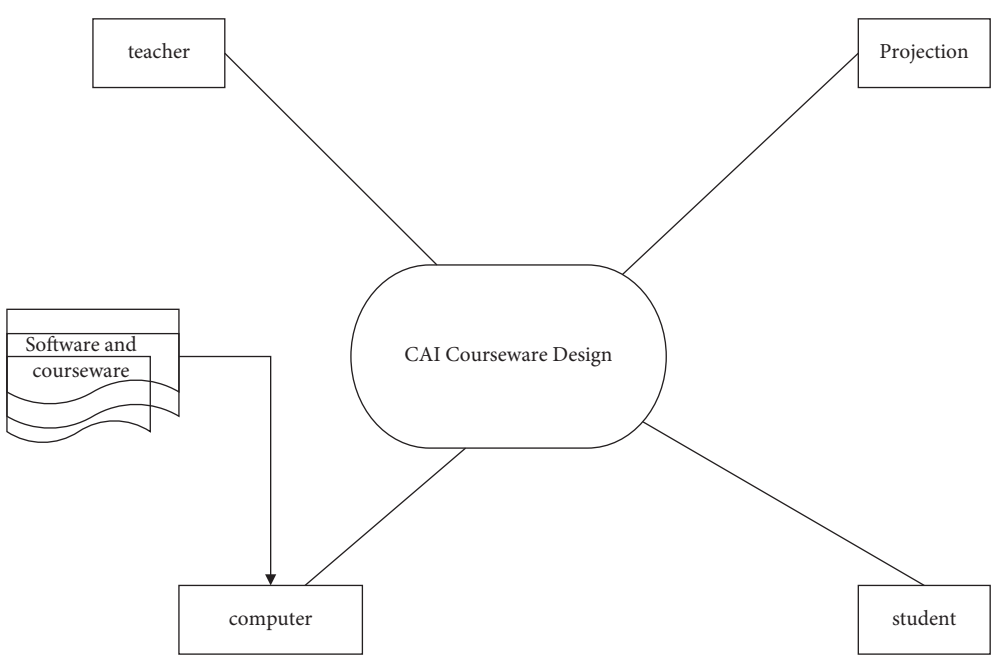

Figure 2: CAI courseware design.

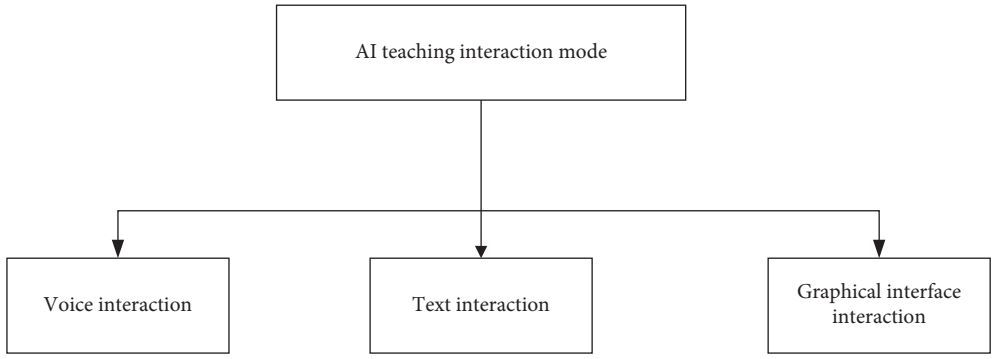

Figure 3: AI teaching interaction mode.

$$TZ_{n\times 30} = \begin{pmatrix} t_{1.1} & t_{1.2} & \cdots & t_{1.30} \\ t_{2.1} & t_{2.2} & \cdots & t_{2.30} \\ \cdots & \cdots & \cdots & \cdots \\ t_{n.1} & t_{n.2} & \cdots & t_{n.30} \end{pmatrix}$$
$$u_{30\times n} = TZ_n = \begin{pmatrix} u_{1.1} & u_{1.2} & \cdots & u_{1.30} \\ u_{2.1} & u_{2.2} & \cdots & u_{2.30} \\ \cdots & \cdots & \cdots & \cdots \\ u_{n.1} & u_{n.2} & \cdots & u_{n.30} \end{pmatrix}. \quad (1)$$

Based on the Euclidean distance formula in the fuzzy concept, the following results are obtained:

$$d_2(x, y) = \left(\sum_{i=1}^{n} |xi - yi|^2\right)^{1/2}. \quad (2)$$

If $x = (x_1, x_2, ..., x_i), y = (y_1, y_2, ..., y_i) \in Rn$, then the Euclidean distance of any learner's feature code similar to this learner is calculated by the following formula:

$$D(x, y) = \sum_{k=1}^{n} \left|u_x(k_x) - u_y(x_k)\right|. \quad (3)$$

If the small value of $D(x, y)$ indicates that the feature similarity between this learner and other learners is high, another learner session mode is recommended for this learner.

In addition, session clustering can be obtained by clustering user sessions using the FCCRD algorithm. The similarity of access patterns among customers in the same session clustering is high, and the access patterns used by users in each session clustering will be different. When the significance threshold and user session clustering are certain, the user painting clustering is generally calculated by using the pr_c method. The formula is calculated is as follows:

$$pr_c = \{\langle p, weight(p, prc)\rangle | p \in p, weight(p, prc) \geq \mu\}. \quad (4)$$

Among them,

$$weight(p, pr_c) = [1/|c|] * \sum_{t\in s} w(p, t). \quad (5)$$

This user session s is as follows:

$$S = \{S_1, S_2, ..., S_n\}. \quad (6)$$

The following formula represents the characteristic C:

$$C = \{w_{1c}, w_{2c}, ..., w_{nc}\}. \quad (7)$$

$W_{ic} = \text{weight}(P_i, C)$ if $P_i \in C, 0$, the cosine similarity function is used to calculate the matching coefficient between S and CC, and its formula is as follows:

$$\text{Match}(s, c) = \left[\sum_k (w^c{}_k * s_k)\right] / \left\{\left[\sum (s_k)^2 * \sum_k (w^c{}_k)^2\right]^{1/2}\right\}. \quad (8)$$

If Recommend(p, s) is used as a measure to determine whether to recommend to learners, it is necessary to set a threshold or set the highest value on the recommendation page and select several larger pages in Recommend(p, s) to recommend to learners. Due to the different ways of recommending pages during customers' visit time, Web mining technology or Web structure mining can be used to calculate the recommendation coefficient of Web pages and judge whether to recommend to learners according to the recommendation coefficient. The calculation formula is as follows:

$$\text{Recommend}(p, s) = [\text{weight}(p, s) * \text{match}(s, c)]^{1/2}. \quad (9)$$

4.3. English Teaching System Based on Computer-Aided Technology. The English Teaching of computer-aided technology shows the characteristics of teacher guidance. Teachers guide students from the learning track of students or complete English teaching directly by using computer-aided technology. This technology will determine the learning content according to the students' learning behavior and then will give feedback to the teachers. After receiving the students' learning behavior, the teachers will carry out personalized teaching and heuristic teaching. The components of this English teaching include an expert system, a knowledge base, and the students' cognitive model, which is shown in Figure 4 [17].

4.3.1. Knowledge Base. The knowledge base stores the knowledge of various disciplines to be taught, including declarative knowledge, meta knowledge, and process

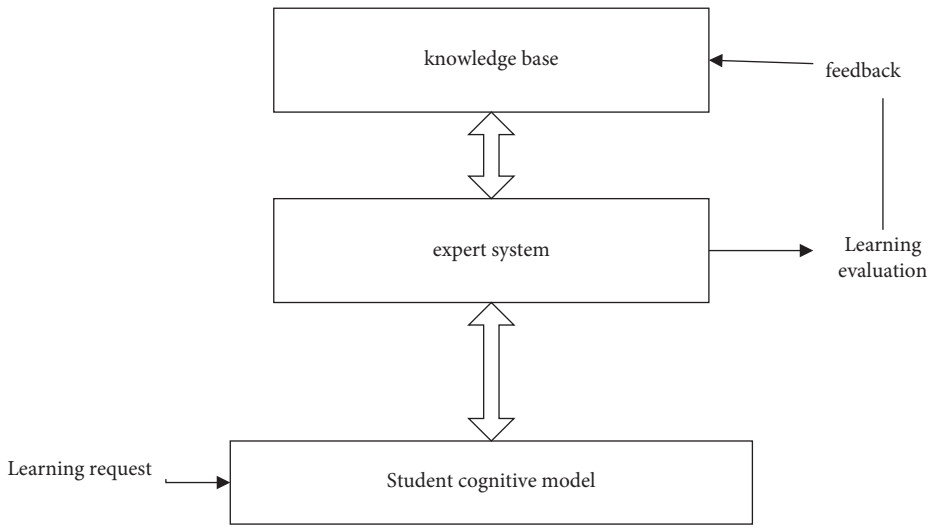

Figure 4: English teaching model.

knowledge. The time is gradually extended, and many knowledge base contents will be accumulated in the next round. In combination with the actual requirements, all kinds of knowledge will be retrieved and queried, questions will be generated, and then, the content of students' answers will be evaluated.

4.3.2. Expert System. The expert system makes intelligent teaching decision according to the content of the knowledge base and students' cognition. The learning process directly determines the learning methods and learning contents to be taken in the next step and can formulate modification opinions and strategies for the evaluation of the students' learning effect.

4.3.3. Student Cognitive Model. The students' cognitive ability and cognitive level are all preserved in the cognitive model. Starting from the students' real cognitive level, we know the students' learning situation and dynamically adjust the learning situation according to the learning situation. If there is new English teaching content, it can automatically provide students with new learning content suggestions according to their previous learning records. The expert system makes scientific decisions according to the students' cognitive model so that the system can accurately evaluate students' knowledge learning and understanding and formulate corresponding teaching activities in combination with all students' characteristics and differences.

5. Analysis of the Effectiveness of English Teaching

This research examines the benefits of internet-based computer-assisted language education in English course instruction, as well as English teaching examples. This section evaluates the analysis of the experimental results concluded and analyzes the effectiveness of the English course teaching.

5.1. Analysis of the English Teaching Effect. This paper uses computer-aided technology to study the effectiveness of English teaching and divides English teaching into two processes: first, teaching and learning, as the main body of the teaching process. The second process is English practice and testing, which is used to feed back on the effect of English teaching in the previous stage and find out the weaknesses of students in the English learning stage. To improve and adjust English teaching activities, the students can fully grasp the differences between themselves and English teaching objectives. They can make continuous efforts according to English teaching objectives [18]. The cycle is too long, which leads to students forgetting some of the test contents, and students cannot find their own loopholes and shortcomings, at the same time, resulting in a lack of continuity of teaching. Nowadays, the use of computer-aided technology in English teaching has changed the traditional practice methods. Firstly, the practice is put on the network test system. Secondly, students use the network to select the test questions or exams previously stored in the question bank and then submit the test scores. Teachers can browse students' English teaching practice on the system. After adjusting the test method, the teaching effect can be fed back to the teacher for the first time. The teacher can readjust the teaching content and progress according to the students' learning situation so as to improve the students' classroom teaching efficiency and practice effect. Moreover, students can obtain the feedback results of practice by using computer-aided technology so that they can understand the learning objectives and direction in the later stage [19].

When analyzing the effect of computer-aided technical English teaching, this paper tests and feeds back 42 words by using the computer and counts the results. The number of words in this test is 42, with ## wrong answers and ## correct answers. The wrong words will be displayed on the computer page, and then, the corresponding Chinese meanings of these words will be listed. After completion, a prompt message will be displayed on the page, "Do you want to

Table 1: Proportion of 1000 word answer pairs in the total number of computer-assisted instructions (total number: 607).

Number of correct English words	Below 50	51–99	100–199	200–299	300–399	400–499	500–599	600–699	700–799	800–899	900–999	Over 1000
Number of correct answers	5	36	24	53	116	68	65	116	18	88	6	11
Percentage%	0.82	5.93	3.95	8.73	19.1	11.2	10.7	19.1	2.96	14.5	9.9	1.8

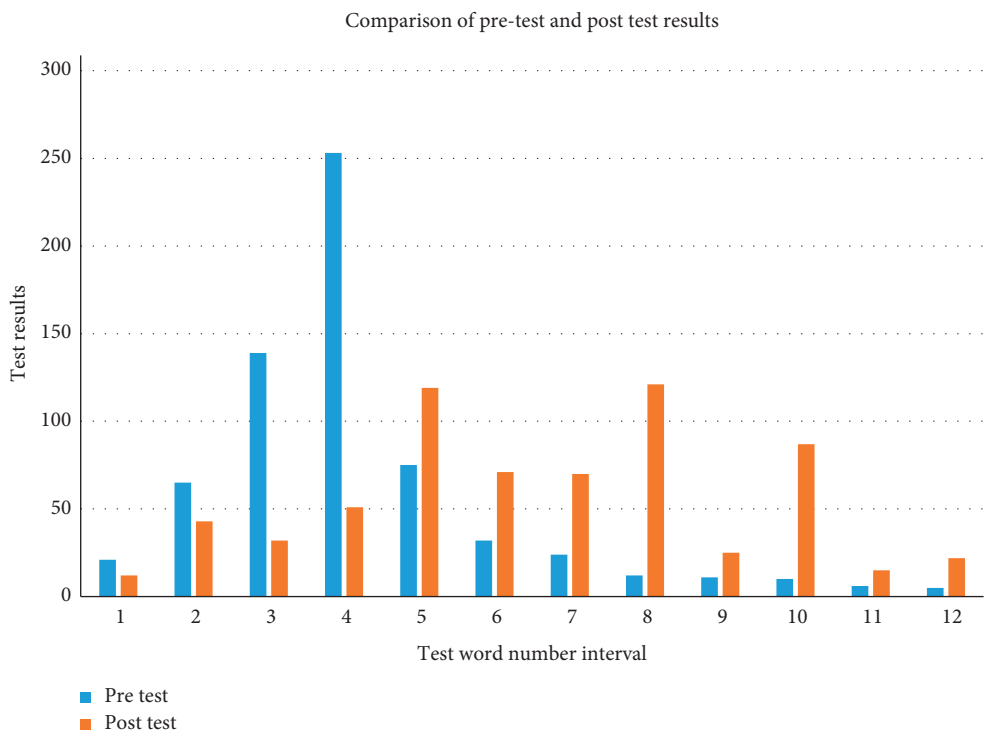

Figure 5: Comparison of the pretest and post test results.

continue learning?" and click start or return. After the students press the return button, they can jump to the learning page and learn the wrong words again. After learning, the computer-aided equipment will test the students' learning situation, recycle the above links, and guide the students to learn all the words in this unit until all the words are clearly remembered and the answers are correct.

When testing the effect of English teaching, three months after the end of learning and an interval of two weeks are chosen. The test paper tested before is used to retest and record the test results, which are shown in Table 1.

There are obvious changes in the data comparison before and after the test. Here, the bar statistical chart is used to display the results of the pretest and post-test for comparison, which is shown in Figure 5.

According to the data in Tables 1 and 2 and Figure 5, the students' scores before and after the test are shown. The results show that in English teaching, the number of English word segments that students have answered correctly based on computer-aided technology is gradually increasing, especially from 0–399 cumulative word segments. The cumulative proportion of people with more than 0–1000 words is as high as 99.8%. The cumulative number of correct English words shown in Figure 5 is fewer than 50, which is represented by 1. The number of 51–99 words is represented by 2. The number of 100–199 words is represented by 3. The number of 200–299 words is represented by 4. The 300–399-word quantity segment is represented by 5. The 400–499-word quantity segment is represented by 6. The number of 500–599 words is represented by 7. The number of 600–699 words is represented by 8. The number of 700–799 words is represented by 9. The 800–899-word quantity segment is represented by 10. The 900–999-word quantity segment is represented by 11. More than 1000 words are represented by 12. After the test, the maximum number of students' cumulative correct English words is 300–399. This result demonstrates that, with the assistance of computer-aided technology, the cumulative number of right English words among students continues to rise, which is beneficial to students' English course learning.

5.2. Analysis of the Effectiveness of English Course Teaching. To analyze the effectiveness of English teaching, two classes of students are selected to take a composition test in the first week of school and at the end of the semester, which is required to be completed within 45 minutes. Then, start from word grammar, spelling, sentence pattern collocation,

Table 2: Cumulative number of people in different grades.

Number of correct English words	Below 50	51–99	100–199	200–299	300–399	400–499	500–599	600–699	700–799	800–899	900–999	Over 1000
Number of correct answers	5	42	65	117	236	301	369	482	503	588	597	606
Percentage%	0.82	6.9	10.7	19.3	38.9	49.6	60.8	79.4	82.9	96.9	98.4	99.8

Table 3: Frequency of errors in the pretest and post-test results of students in the control class and the experimental class.

	Pretest		Post-test	
	Experimental class	Control class	Experimental class	Control class
Frequency of lexical errors	98	89	51	58
Frequency of grammatical errors	35	55	21	32
Frequency of errors in sentence pattern collocation	40	11	22	20
Frequency of errors in coherence	21	14	3	6
Cumulative error frequency	194	195	97	116

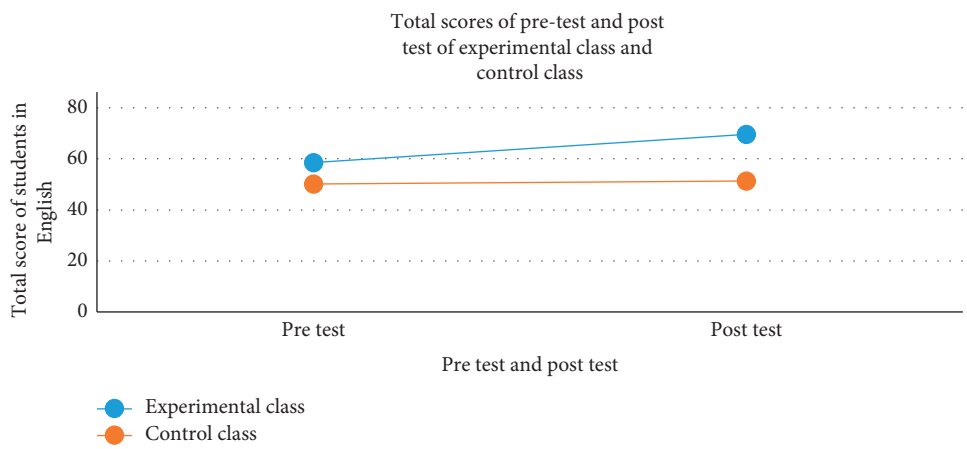

Figure 6: Total scores of the pretest and post-test results of the experimental class and the control class.

and conjunctions, the purpose is to find the number of errors in students' English composition and list the error frequency data of the pre-test and post-test in the control version and the experimental class in Table 3 below.

The analysis of the data in Table 3 shows that at the initial stage of enrollment, the English cooperation level of the experimental class and the control class is basically the same. The cumulative total error frequency of the students in the pretest experimental class in terms of English grammar, vocabulary, sentence pattern collocation, and coherence is 194 words, which is basically the same as that of the students in the control class. Then, the computer-aided instruction technology is used in English teaching for one semester. The test results show that the total error frequency of the experimental class is 97 and that of the control group is 116. Compared with that, the error frequency of the student group decreases more, which shows that the computer-aided technology has a great improvement in English teaching and can help students master more English skills. The pretest and post-test results of the experimental class and the control class are shown in Figure 6.

The experimental results of middle school students are shown in Figure 6, and the average score of students in the experimental class increased from 58.6 to 69.6, while the average score of students in the control class increased from 50.2 to 51.3, with little change. It is fully proved that the total English score and translation ability of the experimental class have greatly improved after using computer-aided technology. However, the control group's score without computer-aided technologies did not increase much. This demonstrates the optimum effect of computer-aided technology in English instruction.

6. Conclusions

In the twenty-first century, computer technology has developed rapidly. Computer-aided teaching technology around computers has become the main teaching method at present. The application of computer-assisted instruction can speed up the students' learning progress and improve the students' memory. Presently, computer-aided technology is widely used in physics, art, and other disciplines, while it is less used in English teaching. Computer-aided technology can design teaching methods in combination with teaching, artistry, and teaching objectives. It also recommends appropriate English learning methods for them so as to establish the English course teaching system of computer-aided technology. Teachers can only formulate teaching

plans according to the process. Through in-depth analysis of the classification framework and basic concepts of computer-aided technology, a computer-aided technology English teaching system is established to judge the quality of English teaching. When analyzing the effectiveness of English teaching, the student's English writing ability is tested. The results show that the error rate in English composition has reduced after teachers adopt computer-aided technology, and the total score of English has increased from 58.6% to 69.6%. After using computer-aided technology, the student's English level has improved faster. Based on this study, a lot of new algorithms can be formed to deeply analyze and improve the efficiency of computer-aided technology and AI technology in building new models for students. The theory can help build up and propose new solutions to the present research problems and evaluate them more efficiently involving less manual labor and timesaving.

Data Availability

The data of this paper are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Application and Design of Drama Popular Science Education Using Augmented Reality

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In the 21st century, the research and development of all kinds of intelligent equipment have become an increasingly important part of people's daily life. Various emerging technologies are developed based on hardware equipment, such as augmented reality (AR) and virtual reality (VR), which fully utilize computer vision technology to accomplish various purposes. Nowadays, it is difficult to carry out opera popular science education in China. Because opera teaching is boring and some traditional opera knowledge is obscure and difficult to understand, it cannot arouse students' interest in learning. Therefore, this article uses VR technology to stimulate students' learning initiative and complete drama science popularization education with rich and colorful teaching means. It first briefly introduces the concept and characteristics of AR technology. After that, it establishes an AR-enabled drama application as an education model based on the statistical entity recognition algorithm and designs the drama popular science education app. Besides, it completes the drama animation design, character modeling design, drama scene design, logo pattern design, and animation design. Finally, from the two points of students' mastery of opera and learning opera knowledge, the actual use effect of this application is analyzed. The results show that this application can help students better learn opera: 42% of students can better master opera singing, 23% of students say they can master other types of opera, 18% of students can better learn and master opera movements and posture, and 10% and 7% of students can master a lot of opera knowledge.

1. Introduction

The advancement of media has been accelerated by the continuous upgrading and development of digital technologies. Information dissemination has transited from the original traditional media to the new media. A variety of induction devices and high-tech devices have been introduced. As a new emerging technology, augmented reality technology (AR) has become mature and widely used in various fields of science and technology, such as education, art, medicine, exhibition, and science popularization. Users use AR glasses to achieve multidirectional, multidimensional space-time scheduling, thus observing more virtual scenes and situations. Augmented reality (AR) is a technology that enables virtual things to be placed dynamically over real-time pictures [1]. This system delivers virtual elements and real-time pictures simultaneously and synchronously [2]. In augmented reality, virtual data are integrated into the user's physical surroundings, allowing the user to interact with the virtual material [3].

AR applications are divided into two categories based on the technology they employ: marker-based and marker-less. In marker-based AR applications, symbolic objects are received by a computer via a marker and a camera, resulting in the presentation of virtual content to the [4]. In marker-less apps, such as location-based AR applications, the user's real-world position is acquired using the GPS, and contextually appropriate virtual data are delivered to the user in regionally important areas. A present study on the usage of augmented reality (AR) apps in drama education shows that such programs have a favorable influence on education and learner attitudes [5]. As per a New Media Center research [6], augmented reality has several potential to transform educational environments, such as improving innovative approaches, teaching methodologies, and the organization and delivery of material, while motivation or skill attainment

is acknowledged as an essential cause for the creation of instructional aids [7]. Educators should evaluate how AR apps might be linked with instructional tactics or pedagogical approaches in drama education, just as they should with AR applications. According to research, using AR in drama education may allow educators to mix such apps with other pedagogical techniques such as contextual learning [8], inquiry-based learning, and game-based learning [9].

In light of the above, the traditional way of popular science education in opera still leads to a lack of students' interest in learning. This article uses the most advanced AR technology to design the educational application of popular science education in opera [10]. Most of the traditional forms of popular science education in opera take the way of broadcasting operas, movies, and TV dramas by showing them to the audience in a programmed way [11]. At the same time, the performance activities will be displayed to students by the personnel of the opera art team in combination with the situation and the way of popular science of opera art. The last is the Opera Art Gallery, which is based on the combination of two-dimensional paper media and three-dimensional screen media propaganda. This form of popular science education in opera is 2.5-dimensional [12]. This traditional form of youth, in which AR technology is utilized to disseminate virtual performance and understanding of opera, has received little support. Therefore, the goal of this technology is to record the complex interaction of opera cuts and so learn more about the popularity of opera science. This article attempts to create an opera popular scientific education application by merging traditional opera art and AR technology, which is suitable for better spreading China's opera art. This will help to promote and advertise the attraction of opera art. In addition, it integrates AR technology into traditional opera teaching by establishing the application of opera popular science education based on AR technology.

1.1. Innovations of This Article. The main innovations of this article are as follows:

(1) Integrating AR technology into the traditional opera popular science teaching, penetrating the traditional opera classroom teaching, and improving the activity of the opera classroom teaching [13].

(2) This article outlines the basic concepts and features of AR technology and introduces the entity recognition algorithm based on statistics, which is the theoretical basis for designing an APP for opera science education based on AR technology.

(3) Detailed description of the establishment of AR-based application process of popular science of opera, design of opera character shape, scene, logo pattern, and animation design, and set up a large Opera Dance database.

1.2. Organization of the Sections. Section 2 discusses the relevant work of national and internal scholars in the chosen field. Section 3 is based on the material chosen and the technique recommended. Section 4 describes the concept of an opera popular scientific teaching program based on augmented reality technology. Section 5 examines the outcomes of opera popular science education, and Section 6 brings this work to a close.

2. Related Work

These days, the world has entered a new era of technology, due to which foreign countries have remarkable advantages in this technology especially network technology. Diverse businesses have made various techniques, although AR enhancement technology is a large-scale commercial technology. Most technology firms started to investigate AR augmented reality technologies [5]. According to reports, AR technology can boost company attention by increasing business revenue [14]. Augmented reality is a new technology that enables various items, elements, and activities that cannot be accessible or implemented in real life to take place in the complexity of the actual world [15]. As a result, many national and international experts are focusing their studies on AR these days. The efforts of some AR researchers are detailed in this section.

The scholars of Ref. [16] studied site-based AR technology in the Science Museum, which is developed and applied on a computer so that visitors can watch AR effects on their computers, making AR technology significantly easier to use. Similarly, the early work of [17] constructs a school theater model for adolescents. The theater in the framework of this project is considered a special educational communication environment in which adolescents can experience the particularity of opera and learn more about the unknown, roles, and relationships. In this regard, the authors of Ref. [18] combine qualitative and quantitative approaches to clarify the social skills of opera teachers, use descriptive and meta-analysis methods to analyze the impact of drama on communication skills, and use social skills to evaluate the teaching social skills of opera teachers. In Ref. [19], the author investigates the current situation of local opera course development in Shaanxi, analyses the current problems of opera textbooks, and formulates a systematic and complete program for developing local opera courses from the aspects of training teachers, compiling teaching materials and teaching strategies. Similarly, the early work of Ref. [20] chose Zibo region local opera for research, based on music textbook course as the carrier, to analyze the problems encountered in the opera popular science education course, and to provide a basis for the use of five-tone opera in our school courses.

Based on the above, the author in Ref. [21] focuses on the analysis of traditional local opera teaching methods in the classroom and proposes to carry out opera science education in combination with campus cultural construction and opera education. Zhou Wei analyzed the problems that need to be dealt with urgently in the current opera class, used the mainstream media to build the national formula, and combined with the secondment training to strengthen the construction of the teaching staff, while, in Ref. [22], the author starts from a psychological perspective to analyze the

problems encountered in the teaching of traditional Chinese opera, arouse students learning initiative and interest, and deal with them by shortening the distance between students and the education of traditional Chinese opera and strengthening students' creative thinking and ability. Cheng Fang pointed out that the teaching team of traditional Chinese opera fully studied the teaching of traditional Chinese opera, searched for a large number of documents and materials, and analyzed the law of traditional Chinese opera teaching by way of tutoring. In Ref. [23], the author uses the idea of teaching and playing, uses mobile APP development, AR technology, and three-dimensional animation technology to design opera character scenes, and designs AR interaction that can effectively stimulate user's cognitive effect, reduce interaction function, and improve application effect. Inspired by the work of the aforementioned scholars, this article uses VR technology to stimulate students' learning initiative and complete drama science popularization education with rich and colorful teaching means. It first briefly introduces the concept and characteristics of AR technology. After that, it establishes the AR technology drama popular science application education model based on the statistical entity recognition algorithm and designs the drama popular science education app. Besides, it completes the drama animation design, character modeling design, drama scene design, logo pattern design, and animation design. Finally, from the two points of students' mastery of opera and learning opera knowledge, the actual use effect of this application is analyzed.

3. Materials and Methodology

3.1. AR Technology Overview. Augmented reality technology is abbreviated as AR technology. This technology uses computer technology to use virtual information in the real world by superimposing virtual objects in the same space or picture as the real environment. Augmented reality technology may deliver perceptual information that varies from human understanding and completely show real-world and virtual data. It accomplishes the goal of mixing virtual reality with augmented reality technologies by superimposing and augmenting two separate pieces of information, perfectly reflecting the features of three-dimensional registration and real-time interaction [24]. AR technology is based on video games and uses new technologies to strengthen what you hear, what you hear, what you hear, and what you feel, making the boundary between the computer-generated virtual world and the real world increasingly blurred. The spectrum between virtual reality and the real world is used to enhance the realization of the real world [25]. AR vision is that users use scanning to mark the objects to be recognized, to superimpose the dual visual feelings of "real" and virtual on the screen. Users use the intermediate medium of executing commands to enhance visual interaction.

AR technology is a virtual influence generated based on a computer system, which enhances the degree of users' perception of the real world. Generally, the implementation effect of this technology is related to the development of AR technology. Compared with traditional technology, this technology can provide users with the effect of immersing themselves in the virtual world. When using AR technology to design popular drama science applications, the basic principle is to fully integrate dynamic layout graphics, sound, and other sensory functions and static patterns. As a result, smooth connections between the actual and virtual worlds are achievable. When designing AR systems, there are several application programming interfaces and toolkits available, such as Mr tool, AR toolkit, and coin3d tool. When developing an AR drama popular science education application, the core engine is unity 3D, and the external connection with the Vu Foria package is employed [26]. The remarkable advantages of the Vu Foria tool are cross-platform and high editing efficiency. This technology locates the video detection function on the tag. Among them, the calibration accuracy of the tag tool and AR camera is higher. At the same time, it supports real scene fusion and specific graphic sound effects, video, and so on. When designing the application of drama popular science education based on AR technology, monitor-based technology is used. This technology has a simple function and implementation process and strong customer understanding and operability, and can meet the basic requirements of drama art lovers. The implementation process of the monitor-based augmented reality system constructed in this article is shown in Figure 1.

3.2. Components of AR Technology. Figure 2 depicts the major components of AR technology: hardware, software, and the remote server.

3.2.1. Hardware in Augmented Reality. Augmented reality devices are outfitted with CPUs, input devices, cameras, and displays. These are mini-supercomputers housed in tiny wearable devices. They demand a lot of computing power and include things like a processor, flash storage, RAM, GPS, GPU, Wi-Fi, and BT. Sensors positioned outside of the augmented reality gadget convey to the CPU the user's interaction with real-world elements. These sensors might be inertial sensors or gyroscopes on portable devices. Cameras are also put outside the gadget to scan the nearby surroundings and capture important data. These data are used by equipment that creates a virtual model to determine the right output. Mirrors are also utilized to help our eyes see the virtual picture more clearly. While several augment reality equipment features a variety of small curved lenses, others only have double-sided mirrors. This mirrors' one objects reflect light rays onto a camera, while the other side bounces light from a side mount screen to the eye. A mobile device, screen, head-mounted display (HMD), or spectacles can all be used as displays.

3.2.2. Software in Augmented Reality. The operation of augmented reality gadgets is heavily reliant on software. D'Fusion and other specialized 3D software are used to

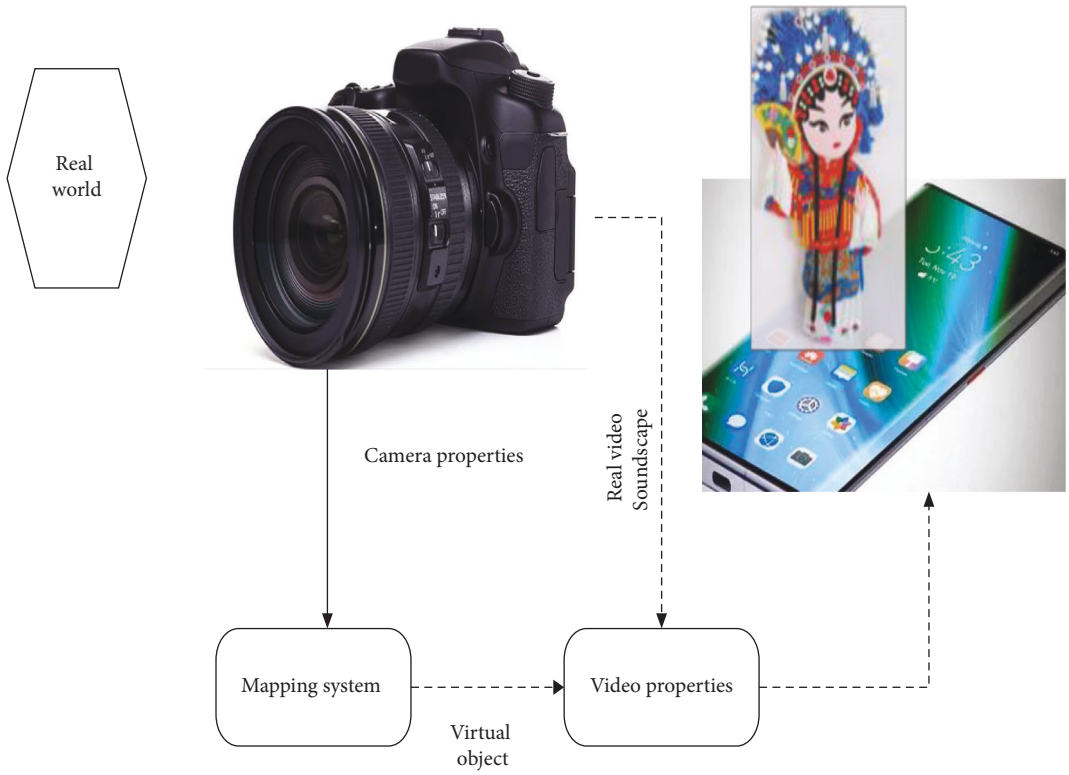

Figure 1: Implementation process of the monitor-based augmented reality system.

create augmented reality apps. Virtual pictures that overlay the real-world image are created using 3D software. Some instances are StudioMax, AutoCad3D, and Cinema 4D.

3.2.3. Remote Server in Augmented Reality. Aside from the hardware or software, an Internet or web server is utilized to keep a database for scanning virtual pictures. Virtual photos will be fetched from the database and given on to the querying augmented reality applications upon demand.

In education, augmented reality is utilized to create a common syllabus. Graphics, video, text, and music can be placed on the actual surroundings of the student. It has permitted the introduction of interactive reading tools that supply pupils with supplementary information. They may now engage with and understand their new surroundings. Augmented reality encourages remote collaboration by allowing teachers and students from many locations to communicate through a similar educational environment.

3.3. AR Technical Features. As we know, augmented reality (AR) is an improved representation of the real physical universe made possible by the use of electronic visual components, music, or other sensory stimulation given through technology. It is a developing trend among organizations active in personal technology and, in particular, commercial apps. With the advent of data collecting and analysis, one of the key aims of augmented reality is to emphasize certain elements of the physical environment, enhance knowledge of those qualities, and extract useful and accessible information that can be used for real-world applications. Big data may help organizations make better decisions and gain insight into customer spending habits, among other things. The key technical features of argumenta reality are explained in Figure 3.

3.3.1. Virtual Reality Superposition. Augmented reality technology is realized by superimposing and fusing virtual objects and reality, or further improved and improved based on the existing environment, which can better connect the virtual world and the real world, to improve the effectiveness of virtual reality fusion. The virtual reality mutual village technology can strengthen people's perception of reality and let users experience a new sense of super time and space, and the effect is enhanced.

3.3.2. Instant Interaction. With the rapid development of science and technology, the traditional single form of interaction cannot meet the basic needs of users. Users urgently need to use a real-time interaction mode. The emergence of augmented reality technology provides people with real-time interaction technology integrating virtual reality and real scenes. The overlay virtual and visible scene is presented by scanning the identification card using computer equipment. Under this scene, users can freely manipulate the virtual scene, strengthen the real-time interaction with users, strengthen the sense of immersion

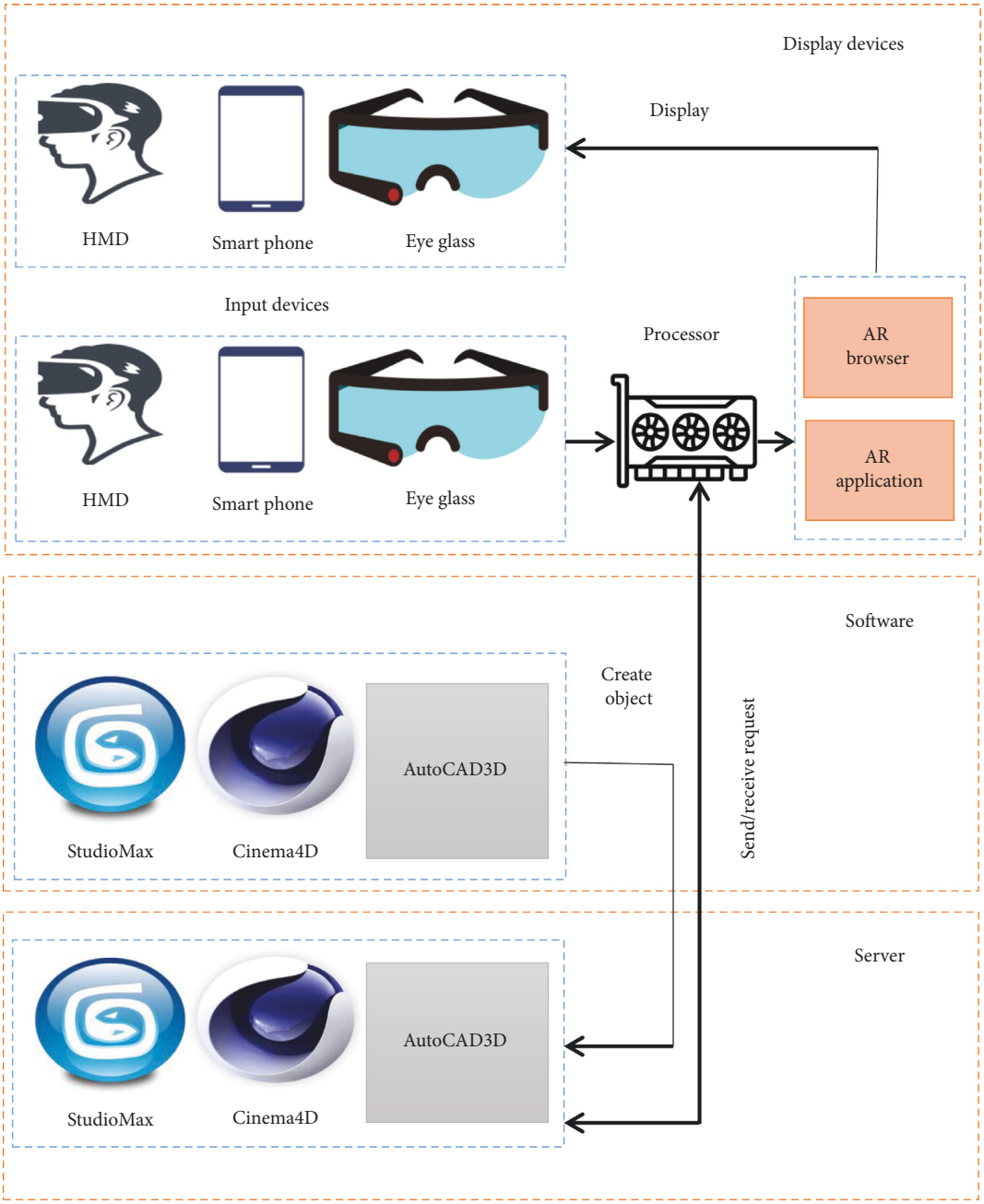

Figure 2: Components of AR technology.

and participation of users, and let users have more different interactive experiences.

3.3.3. D Tracking. The rapid development of AR technology effectively strengthens the recognition ability of AR application equipment. AR equipment's capacity to recognize entities has progressed from two-dimensional to three-dimensional. It can recognize the majority of real-world things. In addition, it can also compensate for the drawbacks of actual situations by strengthening virtual entities in three-dimensional space and replacing entities in real settings. Augmented reality (AR) technology offers more diverse expression techniques that can more thoroughly show multiscale virtual entities and alter virtual entities from numerous viewpoints, allowing for greater integration with the real world.

3.4. Entity Recognition Algorithm Based on Statistics. Entity recognition (ER) is a subfield of information extraction that searches for and categorizes certain objects inside a text or text. Natural language processing (NLP) and deep learning are two applications of ER in artificial intelligence (AI). To identify specific information, information extraction relies on ER, which employs models based on grammatical or mathematical analysis. Entities are initially recognized by ER as one of the various types, including

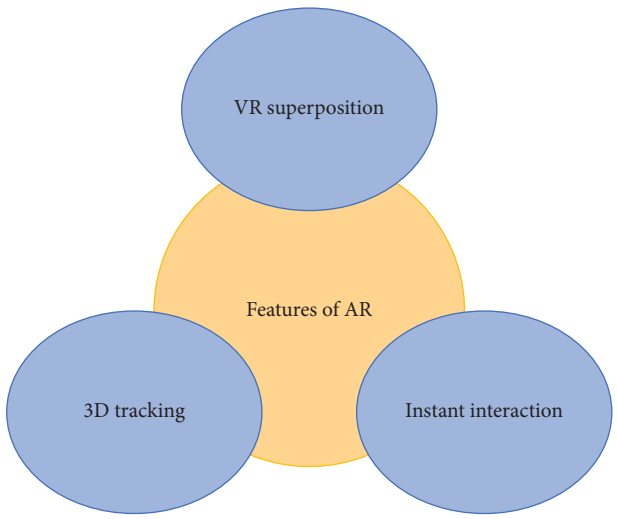

Figure 3: Technical features of AR.

individuals, locations, organizations, statements, proportions, and monetary values.

3.4.1. Hidden Markov Model. The hidden Markov system is a basic method that is used to describe or calculate the probability of any random process. It states that an observed event will not correlate to its step-by-step condition but is connected to a series of probability distributions. Suppose the system being represented is a Markov chain with certain hidden states. In such a situation, we may argue that hidden phases are a procedure that is dependent on the primary Markov process/chain. The primary purpose of HMM is to discover information about a Markov chain by examining its hidden states. Assuming a Markov process X with hidden phases Y, the HMM establishes that the probability of Y for each period must not be dependent on the history of X at that time.

At present, the hidden Markov model (HMM) is widely used in statistical entity recognition algorithms. It is a common statistical analysis model. It uses observable data to clarify the hidden parameters in this process and then uses this parameter for in-depth analysis. At present, it has become the main way of natural language processing, which is applied in the fields of behavior recognition, speech recognition, fault diagnosis, character recognition, and so on.

An HMM is made up of 2 stochastic processes: one invisible of hidden layers and one visible of observable symbols. The invisible hidden layers look similar to a Markov chain and the observed symbol's probability distribution are dependent on the underlying state. Let the hidden Markov model include two random processes, such as $\{x_k, y_k, k = 1, 2, 3\}$. Suppose $S = \{S_1, S_2, S_N\}$ is a state space, where $\{x_k\}$ is an unobservable finite state Markov chain, its transition probability matrix is unknown, and the Markov chain is a state chain, while $\{y_k\}$ is an observable chain, which is called Observation Company. Therefore, the main components of the model are (S, O, π, A, B).

3.4.2. Viterbi Decoding Algorithm. The Viterbi algorithm is a nonlinear programming algorithm for calculating the highest a probability reliable prediction of the most likely series of hidden states, known as the Viterbi route, those outcomes in a series of observed events, particularly in the context of Markov information sources and hidden Markov models (HMM). On the other hand, a Viterbi decoder employs the Viterbi algorithm to decode a stream of bits encoded utilizing a convolutional code or trellis code.

After the model parameters are determined, the next step is decoding, which is the observation sequence and model $\lambda = (\pi, P, Q)$ is certain. Use $v = \{v_1, v_2, v_3, \ldots v_i\}$ to calculate the model $\lambda = (\pi, P, Q)$, and generate the most likely state in the model $x = \{x_1, x_2, x_3, \ldots x_i\}$, inferring the true state of the hidden layer.

The Viterbi algorithm uses forward and backward algorithms to decode and define the path optimal variable and then uses recursive iteration to reduce the amount of calculation. The following is the path optimal variable:

$$\delta_t(i) = \max_{X_1, X_2 \ldots X_{t-1}} P\{X_1, X_2 \ldots X_{t-1}, X_t = S_i, v_1, v_2, \ldots v_i \mid \lambda\}. \quad (1)$$

According to the previous equations, t followed by $X_1, X_2, \ldots, X_{t-1}, X_t$ path, t moment state can be expressed as X_t equal to S_i, generating $V_1, V_2, \ldots$. The probability of V_t observation sequence is the highest. The best possible state transition in S_i at time t is defined when finding the path. Figure 4 explains the flowchart of this algorithm.

(i) *Initialization.* The process of identifying and utilizing the significant measure for variable data used for a computer program is known as initialization. Assuming that the value of t is 1 and I is less than or equal to N, and that there is only one observation and state value greater than or equal to 1, and then, t is the maximum value itself. This can be calculated using the following equation:

$$\delta_t(i) = P\{X_1 = S_i, v_1 \mid \lambda\} = \pi_i q s_t v_t, \quad (2)$$

where state of the S_t is initial and there is no state transition, which can be recorded as $\delta_1(i) = 0$.

(ii) *Recursion.* If $1 < i < N$, $2 < t < n$, $t - 1$ follows $X_1, X_2, \ldots$ At any time, X_{t-1} path by $\delta_{t-1}(j)$ indicates that the state X_{t-1} at $t - 1$ moment is equal to that of S_i, and the resulting $V_1, V_2, \ldots$ The probability of V_t observation sequence is the highest, and $1 \le j \le N$. $\delta_t(j)$ T based on $\delta_{t-1}(j)$ is formed by moving one step to the right. There are N types of states produced by moving one step. Use (3) to calculate the maximum value:

$$\delta_1(i) = \max_{\le 1 j \le N} P\left\{\delta_{t-1}(j) p_{s_j s_i} q_{s_i v_t}\right\}. \quad (3)$$

After extracting items that are not related to j, we can get the following:

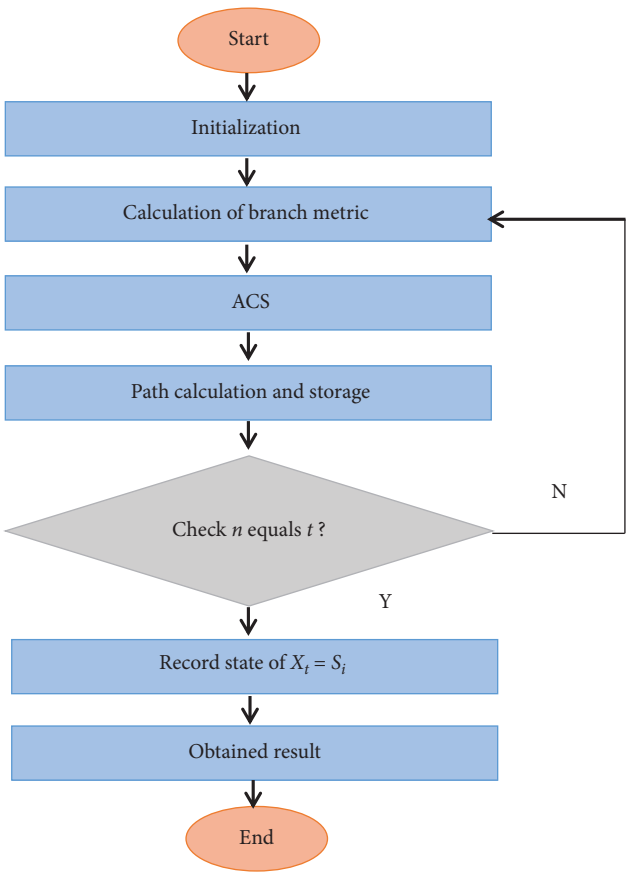

Figure 4: Flowchart of the Viterbi decoding algorithm.

$$\delta_1(i) = q_{s_i v_t} \max_{\leq 1 j \leq N} \left\{ \delta_{t-1}(j) p_{s_j s_i} \right\}, \tag{4}$$

where we record the origin of $X_t = S_i$:

$$\delta_t(i) = \operatorname{argmax}_{\leq 1 j \leq N} P \left\{ \delta_{t-1}(j) p_{s_j s_i} \right\}. \tag{5}$$

(iii) *Termination Condition*. A termination condition is just an expression or a mathematics equation that limits or defines movement by using constants, variables, operators, and shared functions. Here the condition for the proposed algorithm is checked for n equal to t, as shown by the following equation:

$$\delta_n(i) = q_{s_j s_i} \max_{\leq 1 j \leq N} \left\{ \delta_{t-1}(j) p_{s_j s_i} \right\}. \tag{6}$$

The record state of $X_t = S_i$ is formed by the transition from $t = 1$ moment to time:

$$\delta_n(i) = \operatorname{argmax}_{\leq 1 j \leq N} P \left\{ \delta_{n-1}(j) p_{s_j s_i} \right\}. \tag{7}$$

The following represents the optimal probability:

$$P^* = \max_{1 \leq j \leq N} (\delta_n(j)). \tag{8}$$

The n-time state is recorded by the following equation:

$$\delta_n^* = \operatorname{argmax}_{1 \leq j \leq N} (\delta_n(j)). \tag{9}$$

4. Design of Opera Popular Science Education Based on AR Technology

4.1. APP Design of Opera Popular Science Education Based on AR Technology. This article designs the application of popular science education in opera based on AR technology, in which the main carrier of information exchange is APP [27]. The technique of employing AR stereo pictures in the creation and development of popular scientific teaching of opera is explained in this research. After downloading and installing the APP on a mobile platform and scanning the still image, a virtual three-dimensional image will appear on the device screen, as illustrated in Figure 2. When APP scans a still picture, it examines it to see when it satisfies the desired specifications. Specific sound effects and graphics should be added to the relevant database in advance while constructing an APP. Users can proceed with the download of APP software and the preparation after enrolling or activating the program. Based on AR technology, the design of the Opera Education APP can recognize a series of specific opera art features, such as stage, role, and decorative patterns. The design functions include the following:

(i) Image scanning and AR enhance the 3D dramatic stereo animation effect [28]

(ii) Achieving the matching of opera scenes, lyrics, and music

(iii) 360-degree panoramic rotation with functions of zooming out and zooming in

(iv) Intercept specific animation scenarios and share them with other friends

(v) Change the costume of the characters and realize the interaction of the artistic roles of the plays

(vi) Enhance the entertainment of traditional Chinese opera art

Figure 5 shows the design process of popular science application of opera based on AR.

4.2. Enhancement of Functional Interaction. Based on Unity 3D and Vu Foria SDK, this article designs a popular science application of mobile AR opera by using the Vu Foria SDK resource pack to track 2D patterns with identification markers. After that, it combines iOS mobile devices with Android touch screens to generate virtual, real, and interactive two-degree cross-fusion, which can enhance the display effect of an interactive experience.

4.3. Dramatic Animation Design. This article uses Unity 3DAR to design opera animation, involving the design of opera character scenes, role modeling, special effects, and animation design. In the design process, the overall design effect should be analyzed and the interestingness highlighted. The opera characters designed are funny and

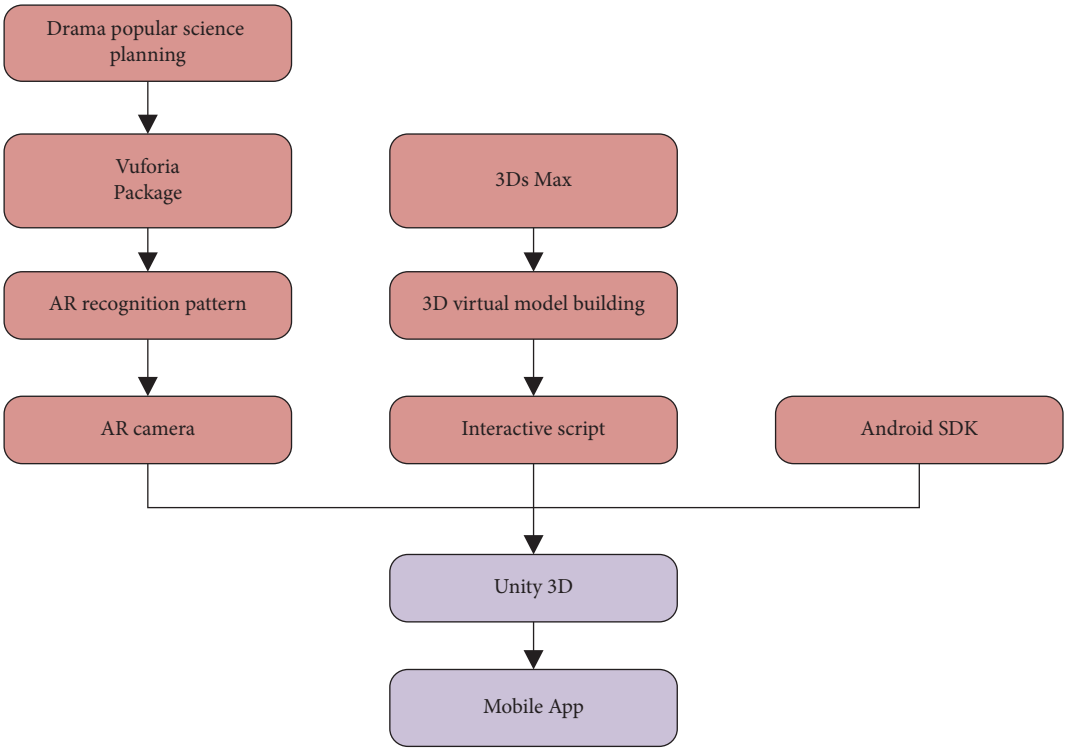

Figure 5: The design process of popular science application of AR opera.

humorous to meet the aesthetic requirements of the popularity. The new and interesting design of the opera can attract more users and play a role in teaching and enjoying. The application of Augmented Reality (AR) technology can enhance convenience, and beginners can learn better. The main contents of the animation design of opera are explained in Figure 6.

4.3.1. Designing the Role Style of Opera. The general impression of traditional opera art is stereotyped, stylized, and rigid characters. Therefore, most people should use the role style design when designing the opera style. This study explores the cartoon characters of AR Opera based on the lessons and pleasures creates in the cartoon forms. For this purpose, this research work follows the basic principle of designing the proportion of roles: the two-body shapes of a big head and small body, and the role clothes are classified according to the different scenes of the opera.

4.3.2. Designing Opera Scenes. Traditional opera performances must be finished on a permanent stage, and audience members can only see them in that setting. The opera scenes made using AR technology may be redesigned and developed from the tale scenes, capturing the complete immersion and presence of the opera sceneries.

4.3.3. Designing Identity Patterns. Based on AR technology, popular science education application design of opera should be divided into different forms when designing and identifying patterns. This article takes the classic sections of Huangmei Opera as blueprints to complete four sets of AR-pattern designs. By identifying two categories of Huangmei Opera, two representative patterns are selected, which meet the requirements of diverse artistic types and styling characteristics of the opera. Enter the mobile phone client again and open the APP to scan the static pattern; the page can display the image of the opera and different stage scenes. After the opening of the opera animation, the music gradually shows its effect. While viewers enjoy the art of the opera, they can also learn more classical Chinese opera poems.

4.3.4. Animation Design. The animation of traditional Chinese opera should be completed according to the accuracy and fluency of the action. When collecting and optimizing the action, it should be analyzed from the aspects of a body, sleeve, law enforcement, etc. The symbolic nature of traditional Chinese opera actions makes them more artistic, and they are the main part of the aesthetic expression of traditional Chinese opera. For example, sailing, walking, mountains, hegemony, and running city in the opera all reflect the dancing characteristics. Therefore, Keyframes should not be used when designing actions. Standardized and standardized action data should be collected. Create a database of opera animations by capturing the movements and processing of professional opera dancers, and then bind it to the three-dimensional virtual characters of the opera. This article uses light motion capture technology to collect dance data of Huangmei Opera, uses Motion Builder to optimize data, and integrates animation data and 3D characters based on 3D sMax 3D animation software.

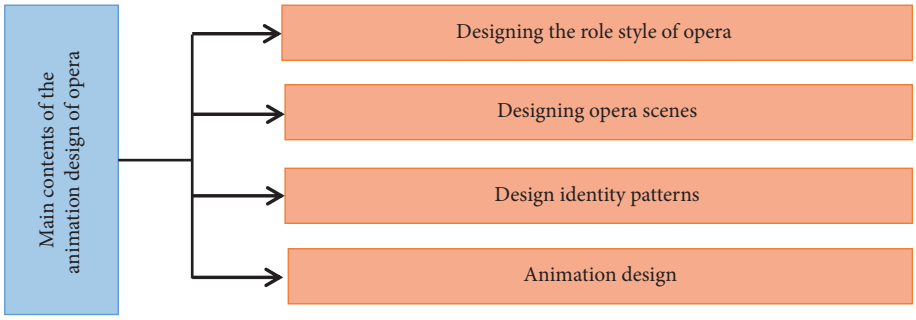

Figure 6: Main contents of the animation design of opera.

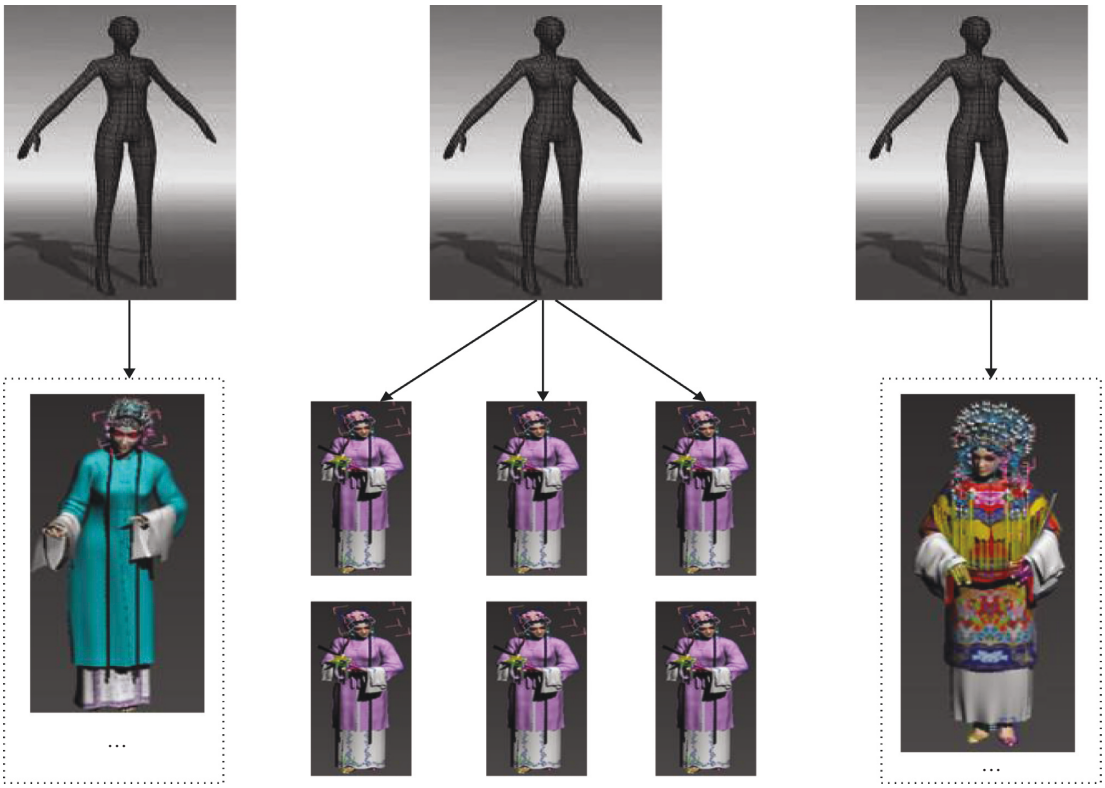

Figure 7: Opera animation database framework.

Compared with the general animation creation method, this motion capture technology can convert the motion data, which greatly improves the efficiency of motion capture without increasing the production costs. It is suitable for building large opera dance action database. Figure 7 is the technical framework of the motion database.

5. Analysis Results of Popular Science Education in Opera

5.1. An Analysis of Students' Mastering of Opera. This article designs a popular science education application of opera based on AR technology and uses it in the actual opera classes. To test the actual effect of this application, a student of an opera school is selected as the research object, starting from three aspects: performance of the opera body, mastering the number of opera segments and mastering the basic

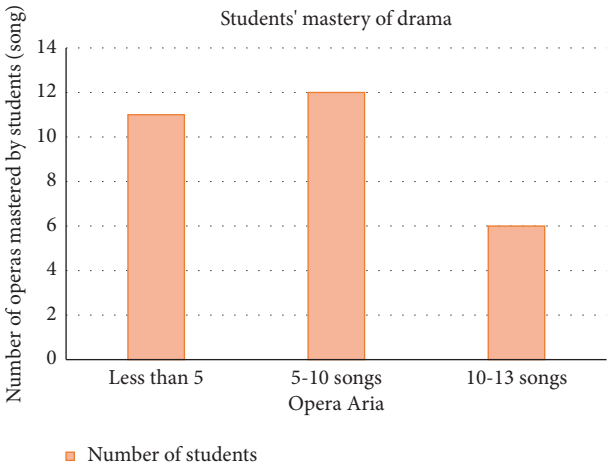

Figure 8: Student opera mastery.

Table 1: Students' master number of albums.

Number of students	Aria name	Number of aria
23	All tracks	6
2	"Drunken Imperial Concubine," Liang Shanbo and Zhu Yingtai "Daughter in Law," "Celestial Match"	4
5	"Drunken Imperial Concubine," "Liang Shanbo and Zhu Yingtai" "Daughter in Law," "Celestial Match," "A Dream of Red Mansions"	5

Table 2: The quality of performance.

Number	Lyrics	Melody	Emotional input	Body movement
1	Relatively clear	Unfamiliar with some paragraphs	Input section selection	Some actions are not in place
2	Partially clear	More familiar	Not very involved	Some actions are not in place
3	Part unclear	Unfamiliar with some paragraphs	General input	Some actions are not in place, Even forget

knowledge of opera. According to the survey data, 6 students of the Opera School can master 10–13 opera segments, 12 students can master 5–10 opera segments, and 11 students can master less than 5 opera segments. The statistical results are shown in Figure 8.

In the course of section teaching, we should learn opera knowledge, mainly including the characteristics of opera singing, the development of opera genres, and the explanation of classical sections in opera [29]. Traditional Chinese opera body movements include basic performance actions, and most students learn independently by watching opera videos. This article analyzes opera education in the opera school from 2019 to 2020 to confirm the data's authenticity and scientificity. To guarantee the authenticity and scientificity of the data, students study six new opera segments, namely, the Beijing opera tracks "Farewell My Concubine," "Imperial Drunken Princess," "Dream of Red Chamber," "Liang Shanbo and Zhu Yingtai" over-opera tracks, "Puma," and "Tian Xian Pai" Huang Mei opera tracks. This article selects 30 students from the Opera School, 24 of whom can master these six opera tracks skillfully in one year. Student's master number of albums can be explained in Table 1.

Three students in Table 2 above are unfamiliar with opera melody, lyrics, emotional expression and body movements, less emotional input and nonstandard movements, and even forget lyrics and body movements.

5.2. An Analysis of Students Learning Opera Knowledge. The opera school uses the popular science education application of opera based on AR technology design to analyze the situation of students learning opera knowledge. According to the survey data, 42% of students said they mastered opera singing in the opera class, such as "Four Gong Five Methods" and "Qichen Dantian"; 23% of the students indicated that they could master a large number of other types of operas, including Huangmei Opera, Beijing Opera, and Yuyu Opera, after applying AR technology to the teaching of popular opera science. Eighteen percent of students said they could learn and master the body and action of opera performance. 10% and 7% of students said they could master more opera knowledge in the opera class. The statistics are shown in Figure 9.

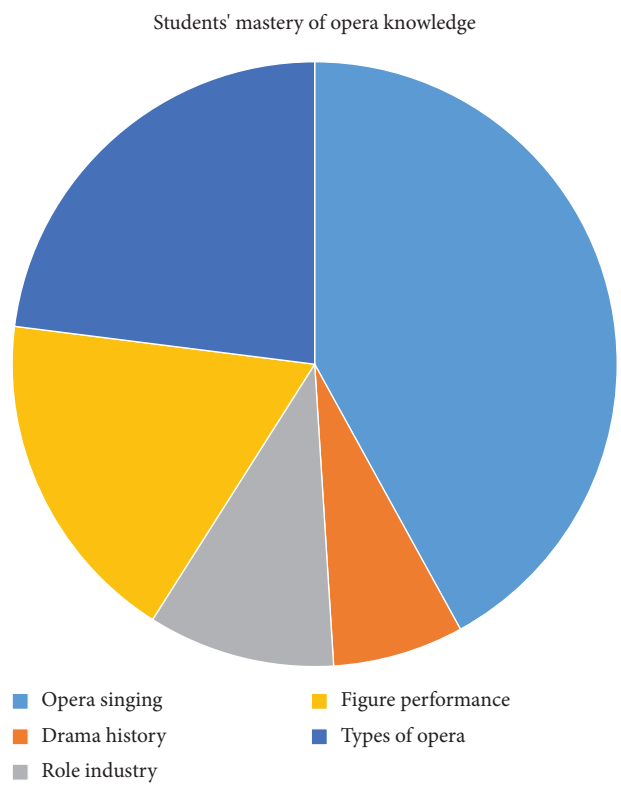

Figure 9: Students master opera knowledge.

5.3. An Analysis of Students' Learning Styles of After-School Opera. This article analyzes the way students learn Chinese opera after class. 60% of them say that they will practice after class when they learn the acting actions and singing passages of Chinese opera, and look up the data of Chinese opera in the application according to the teacher's requirements. 29% of students will learn opera videos independently after class watch and browse the video of opera selections. Only two students will learn opera from primary school and communicate with the opera teacher to learn opera [30] after class. 7% of students will learn opera in other ways, such as watching a competition and performing. Figure 10 shows the statistical results of the way students learn opera after class.

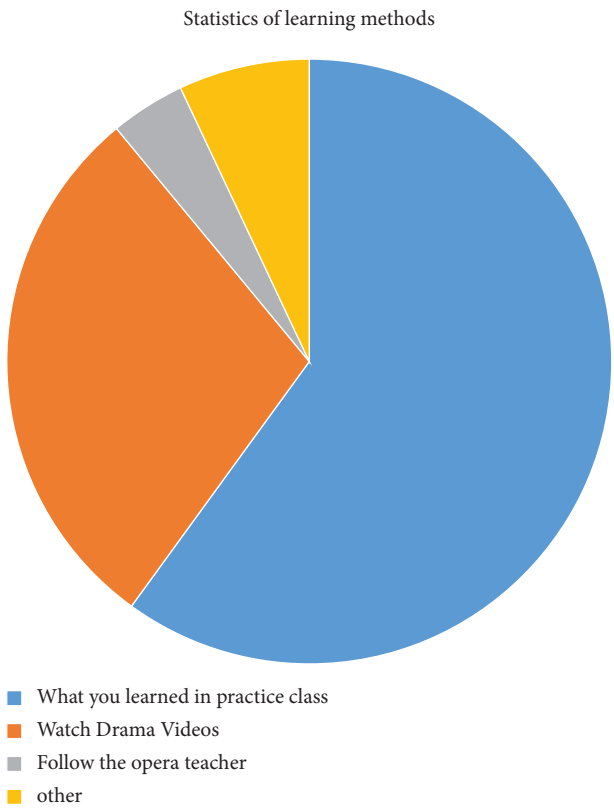

Figure 10: Statistics of learning methods.

6. Conclusions

In recent years, there are many popular science education products developed based on AR technology. However, AR technology is rarely used in drama popular science education, and there are few products developed. Traditional opera popular science education adopts a single way of teaching, the classroom teaching process is boring, and the efficiency and quality of students' Opera learning are low. Therefore, this article uses VR technology to stimulate students' learning initiative and complete drama science popularization education with rich and colorful teaching means. This article first briefly introduces the concept and characteristics of AR technology, establishes the AR technology drama popular science application education model based on the statistical entity recognition algorithm, designs the drama popular science education app, and further completes the drama animation design, character modeling design, drama scene design, logo pattern design, and animation design. Finally, from the two points of students' mastery of opera and learning opera knowledge, the actual use effect of this application is analyzed. Among them, 42% of the students can better master the singing method of drama, 23% of the students say they can master other types of drama, 18% of the students can better learn and master the movement and figure of drama, and 10% and 7% of the students can master a lot of drama knowledge. This fully proves the effectiveness of this application in practical opera teaching, which is of great help to improve the quality and effect of opera teaching [31].

Data Availability

The datasets used and/or analyzed during the current study are available from the author on reasonable request.

Conflicts of Interest

The author declares that there are no conflicts of interest for the publication of this article.

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Research Article

Designing a National Music System for a Smart Concert Hall Using Neural Network and Wireless Internet of Things

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With the fast advancement of science and technology, numerous music systems have emerged. However, there are few folk music in the music industry, for example, pop music, which leads to the inability of folk music lovers to find their favorite music. For this problem, this paper develops a national system of smart concert hall based on a neural network and wireless Internet of things (IoT). It establishes the architecture model of the wireless IoT system of the concert hall by describing the neural network, neuron model, and BP neural network model in detail. Besides, this paper develops the smart music national system based on this model, completes the functional module design of the national music system, and uses the music attribute recommendation model. Finally, it analyzes the scoring performance of the national music system. The results show that when the number of recommended folk music songs is less than 20, the lowest MAE is 0.73.

1. Introduction

Music is a popular kind of entertainment in the digital age. It is defined as a work of human creation that uses sounds to communicate thoughts and feelings via melody, rhythm, and beat. Rock, pop, jazz, folk, and other genres of music may all be classified. Besides, background music in the digital era is made easier by smartphone capabilities that allow us to listen to music online as well as offline [1]. Access to digital music is currently more difficult than in previous times, and thus, searching through all of this digital music takes a long time and results in information overload. As a result, it is extremely beneficial to create music recommendation systems that can automatically scan music collections and recommend songs appropriated for users. Songs services like Netflix such as Spotify and Pandora include features that allow users to be recommended music. These characteristics can assist in obtaining a list of relevant music from popular artists' collections based on previously listened to music. As a result, the recommendation systems are critical to the survival of the streaming music industry [2]. Music suggestions are made by comparing one piece of music to another or by offering priority from one listener to another [3]. The difficulty of a music recommendation system is to design a technology that can constantly locate appealing new music while also understanding the consumers' music tastes [4]. This necessitates that the music personalized recommender system accurately represents human tastes. It requires modifications to create customized suggestions for the needs of various audiences. As a result, the tailored recommender system for music is more complex than the standard recommendation systems.

Many techniques for digital music have been developed, with neural networks and wireless IoT taking center stage these days. The authors of [5] introduced the word in the context of musical instruments that were enhanced with QR codes that directed users to Internet information about the device and its cultural history. The phrase was introduced in the framework of continuous music research by the authors in [6], which includes innovative use of the Internet, portable devices, and integrated technology for continuous musical activities [7]. While the authors of [8] proposed extending the theory of IoT to the musical domain, IoMusT was defined as a subfield of IoT in which the underlying technology environment enables ecosystems of interoperable devices connecting performers and audiences to

support novel musician-musician, audience-musician, and audience interrelations. Likewise, the authors of I utilized the word in the context of practically complete for musical purposes, suggesting an infrastructure to address the effective use of large-scale community-generated sounds.

Although there are many online music platforms in the market, there are only few related to national music. At the same time, our country pays attention to the cultivation of national music. More and more students are learning about the knowledge and culture of national music. Therefore, more and more people urgently need to develop the national music system to meet their individual music needs [9]. In this paper, the current mainstream network technology and wireless IoT are combined and used to set up a national music system for directing concert halls. My neural network is used to gather my people's favorite types of national music, create a national music library, and disseminate national music on the network through wireless IoT so that more people may discover their favorite national music on the system.

1.1. Contributions of the Paper. The followings are the significant advancements in this research paper: (1) before building this system, the neural network and wireless IoT algorithm, including the neuron model and BP network model, are thoroughly discussed. Based on this, the architectural model of a wireless IoT system in a performance hall is built. (2) Designing and developing the national music system of the intelligent concert hall, introducing each function module in the national music system, and building a recommendation model based on music attributes and a weighted mixed recommendation model based on deep learning.

1.2. Organization of the Paper. The second section of my paper is based on the relevant work of other academics who worked in the chosen field. The third section focuses on my wireless IoT powered by a neural network. Section four goes over my proposed smart concert hall national music system. Section 5 is based on my examination of the national music system's performance. Section 6 brings this paper to a conclusion.

2. Related Work

With the fast development of neural network algorithms, big Internet firms at home and abroad employ artificial intelligence technology to produce more music systems to suit people's individualized music demands, attracting the attention and research of a significant number of specialists [10]. In [11], the authors proposed a method to clarify the user influence degree by using the trust relationship on social networks and then defined the similarity index of collaborative filtering based on the influence degree. In this connection, the authors of [12] pointed out that the MCRN model can accurately extract the music features on the map and use the experimental method to test the advantages of MCRN in recommendation accuracy and music classification. In addition, the authors in [13] used the matrix decomposition technology to obtain the long-term characteristics between songs and users. They used the language processing technology to collect the music context characteristics and then called the long-term and short-term memory network model to train the real data set and to obtain the best experimental result characteristics. In [14], the authors highlighted the problems of the long music classification cycle and low accuracy, and establishing an optimized cyclic neural network model and adding an attention mechanism to the model can improve the classification accuracy. They established a fusion model based on deep learning and collaborative filtering and used the improved neural network mining algorithm and automatic encoder to capture the hidden features in music and to better integrate the collaborative filtering model with the deep learning model.

At the same time, comprehensively analyze the user preferences and music features, to supervise the collaborative filtering process and better deal with the problem of low prediction accuracy caused by sparse matrix [15]. In this regard, the authors of [16] used a convolutional neural network to learn the audio content features of music; its essence is to transform audio into a "spectrum map" by Fourier transform. In [17], the authors proposed a model based on the perceptual characteristics of the human auditory system in music materials, and this paper studies the acoustic aesthetic evaluation method of a concert hall, defines evaluation criteria, and subjectively evaluates the objective acoustic parameters of concert hall. Similarly, the authors of [18] investigated the topic of music emotion categorization using single morphological data. Their model provides a deep confidence network-based multifeature fusion music classification method that extracts feature vectors from many viewpoints and enhances the standard deep confidence network-based music classification algorithm. Finally, the authors of [19] put forward a cross-cultural and cross-time and space national music teaching method based on education and teaching practice, build a complete music classroom teaching structure, and establish a feedback teaching system. Inspired from the work of the aforementioned scholars, this paper develops a national system of smart concert hall based on a neural network and wireless IoT (IoT). It establishes the architecture model of the wireless IoT system of the concert hall by describing the neural network, neuron model, and BP neural network model in detail.

3. Wireless Internet of Things Based on Neural Network

3.1. Neuron Model. Neural networks are simple models of how the nervous system functions. Neurons are fundamental units, which are often grouped into layers. Simple simulations of how the nervous system functions are called neural networks. Neurons are the fundamental units, which are usually grouped into layers as seen in Figure 1.

As per the above figure, the following is a brief description of the components of the neuron model.

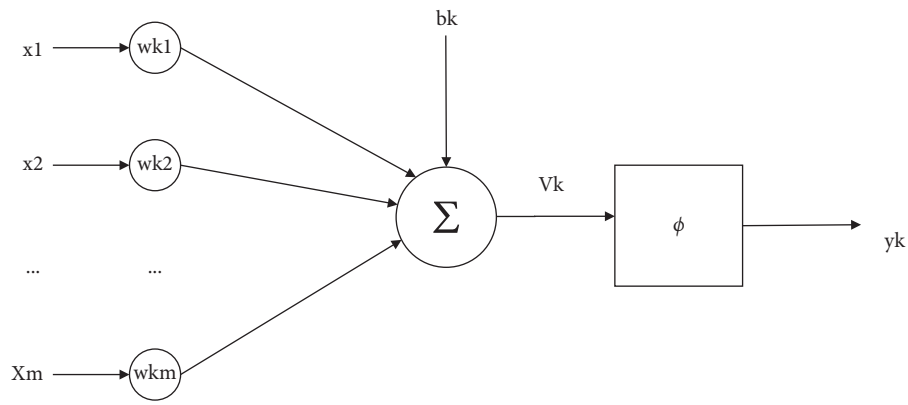

Figure 1: Neuron model.

3.1.1. Connection with Authority. This component simulates the synaptic realization of neurons in the biological nervous system. The strength is judged by the connection weights, positive for activation, and negative for inhibition.

3.1.2. Sum Point. After weighing all the input signals on the neuron model, the linear combination summation computes the weighted values corresponding to the summation points.

3.1.3. Activation Function. The function of this function is to control the output amplitude of a neuron as a controlled region, generally [−1, 1] or [0, 1]. In other words, an activation function describes how the weighting factor of the input is converted into an output from a node or endpoint in a network layer.

3.1.4. Threshold Function. The threshold is the function's cut-off value. So, if we adjust it to 0.5, everything below it produces a 0 result, and anything overproduces a 1. In this comparison, it is the desirable input since it influences the result. In brain neurons, 0 represents no reaction to stimuli, and 1 represents a positive response. The neuron typically fires when the stimulus strength is equal to or greater than the minimum necessary to activate it. The threshold determines the minimum needed energy. The offset and threshold can be calculated using the following equation:

$$u_k = \sum_{j=1}^{p} wk_j x_j, v_k = u_k - \theta_k, y_k = \phi(v_k). \quad (1)$$

In the above equation, $b_k(-\theta_k)$ represents the offset, while θ_k represents the threshold. Similarly to the above, x_1, x_3, $x_3 \ldots$ represents the input signal. The weights of the neuron k are $w_{k1}, w_{k2}, \ldots, w_{kp}$, which means u_k is the result of a linear combination. $\Phi(v_k)$ represents an offline activation function, and y_k represents the output of a neuron.

If you reincrease the number of bits of input data, you can add θ_k, the following is the formula:

$$v_k = \sum_{j=0}^{p} w_{kj} x_j, y_k = \phi(v_k). \quad (2)$$

Add a new connection to the above equation (2), $x_0 = -1$ or + 1 as input data, $w_{k0} = \theta_k$ or b_k denotes weight.

3.2. BP Network Model. This paper uses the BP neural network model for the development of a national music system for a smart concert hall. BP network is one of the most commonly used neural network models. It uses the error backpropagation method to train the multilayer feedforward network [20]. Based on the MP model, [21] suggested and enhanced the learning function, allowing the model to conduct predictive modeling. Various neural networks, including convolutional neural networks, BP neural networks, and risk assessment, involve considering neural networks and, so on, have their properties and are frequently utilized nowadays.

At the moment, the majority of research on the subject of innovation persistence uses regression analysis or nonlinear multiple regressions. Their benefit is the evident exposure of the link among independent factors and response variables; nevertheless, this model cannot be utilized to do more complicated processes, such as pattern classification. Despite reality, the connection among variables is frequently a complicated nonlinear model that is difficult to observe. The BP neural network is a black box technique that may do nonlinear translation without requiring the mappings connection to be determined in advance. Fundamentally, it trains the data, understands the principles, and then produces the anticipated output with the minimum mean square mistake of the actual output. It benefits from a short estimate of the parameters of time, self-learning, self-adaptation, and fault-tolerant. After decades of study and improvement, the BP neural network has emerged as one of the systems with broad application and a strong classification impact. As a result, in my study, the BP neural network is employed to recognize and evaluate patterns.

Apart from the above, the BP network can learn and understand various mapping relationships without knowing the mapping relationship between input-output modes in advance. BP neural network can reduce the error square of the network, while learning rules can adjust the threshold and weight of the network utilizing backpropagation and achieve this goal by employing the gradient descent method.

The network topology components of a neural network include the hide layer, input layer, and output layer.

Forward propagation and reverse propagation are two main components of the BP algorithm. Forward propagation is the secondary forward calculation or external data flow in the initial stage, which first propagates to the input layer, then to the hide layer, and finally to the output layer. Reverse propagation uses the error signal between the correct result and the initial result to correct the weighting process through reverse inference. The calculation process of this algorithm is that each layer of neurons in the neural network can only affect the lower layer of neurons. If the difference between the expected and initial results is considerable, the algorithm will automatically transfer the incorrect value to the reverse propagation step. When the weighted vector result is 0, the network model uses an error function gradient descent technique. During this process, overlapping loops use forward and reverse propagations to create a dynamic search for each pair of weighted vectors, minimizing the error function and performing data identification and extraction.

3.2.1. Forward Propagation. The input layer of the BP network model consists of three nodes, six nodes in the hide layer, and three nodes in the output layer. If *vki* denotes the weight between hiding and input layers, *wjk* denotes the weight between output and hide layers. In the forward propagation process, the input layer is first passed into the recessive layer and then into the output layer. Each layer of nerve and Anu state affects only the lower neurons, and the other layers are not disturbed. Figure 2 shows the forward propagation topology of the BP network model.

According to the above figure, f1() is the transfer function for the hide layer, f2() is the transfer function for the output, and the value of k ranges from1 to *p*. The input layer can be calculated using the following equation:

$$z_k = f_1\left(\sum_{i=0}^{n} v_{ki}x_i\right). \tag{3}$$

Equation (4) calculates the output layer node output.

$$y_j = f_2\left(\sum_{i=0}^{q} w_{jk}z_k\right). \tag{4}$$

The approximate mapping between m-dimensional space and n-dimensional space vector in the BP network model can be achieved by the above equations.

3.2.2. Backpropagation. Backpropagation is the foundation of network training. It is a way of fine-tuning neural network weights depending on the error rate achieved in the previous loop. By fine-tuning the weights, you may minimize error rates and make the design more dependable by boosting its generalization. The backpropagation (PB) network structure is a multilayered feed-forward neural network that has been developed using the error backpropagation technique. An example in a BP neural network contains *n* inputs, *m* outcomes, and multiple hidden layers between both the input layer and the output layer. By adding the backpropagation mechanism to the neural network model, the neural network can be guaranteed to have a high recognition, strong self-correction ability, and a higher recognition and data processing ability.

3.2.3. Architecture of Concert Hall Wireless Internet of Things System. The IoT is a critical network design on the system network, making it more manageable, easier to run, and standardized in the future. China divides the IoT system into three levels: network layer, perception layer, and application layer [22]. The concert hall installs power equipment in the substation layer. By combining with the traditional three-tier network architecture system of the IoT, a three-tier system of wireless IoT for the virtual concert Hall is established in this paper. My proposed system consists of a data transmission layer, device monitoring layer, and application layer. Figure 3 explains the architecture of concert hall wireless IoT system.

Here are the basic roles of each layer in the architecture of the concert hall wireless IoT system.

(i) Monitoring layer: The monitoring layer is responsible for constantly operating my system. This layer is the backbone of the functioning of my system. On the monitoring layer, various IoT devices such as Wi-Fi and ZigBee are installed. Wired devices provide a higher quality of service, but more wired devices will increase the difficulty of later system maintenance. Compared with this kind of wireless IoT, it is more scalable and flexible to use. Each monitoring point can control the device in real-time. After collecting data, the IoT devices will generate clusters to send to the receiver or gateway using a virtual multiantenna system. A gateway receives data, provides a path to it, and transmits it to the network layer.

(ii) Transport layer: This is another critical layer that allows communication across application processes operating on multiple hosts in my model as well as other network components. The transport layer in my system takes message segments from apps and sends these into the network. It includes a wide range of wireless local area networks, including WiMAX, PLC, 4G, and others. The primary function is to provide the system with a dependable network transmission channel via which data from the monitoring layer may be transmitted and used by the application layer.

(iii) Application layer: End-user applications such as Internet browser programs make use of this layer. In my approach, it offers controls for the program to send and receive data as well as show useful facts to consumers. This layer contains several monitoring systems, such as measurement equipment, monitoring management systems, gathered data information, and others. One of the main components is the application layer monitoring system, which can

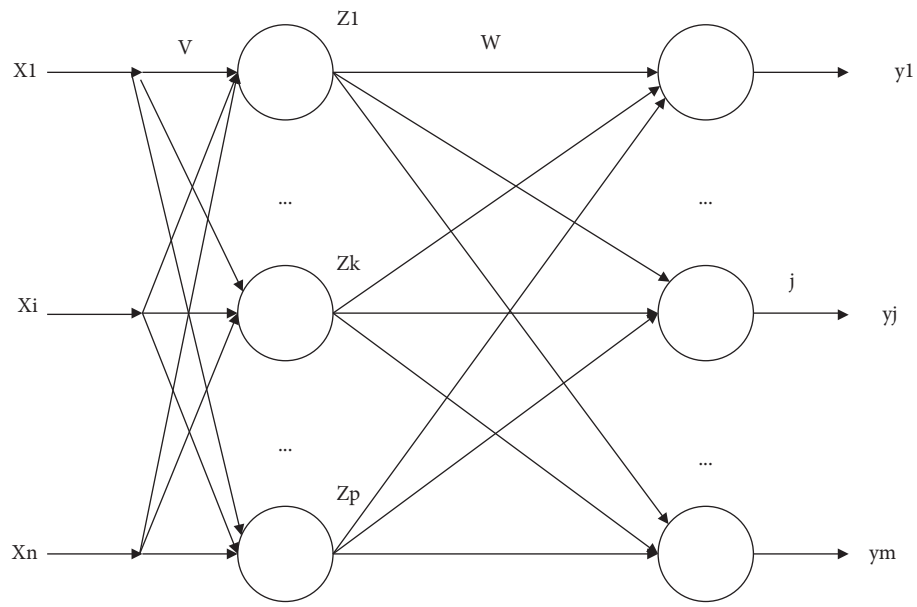

Figure 2: Three-layer neural network topology.

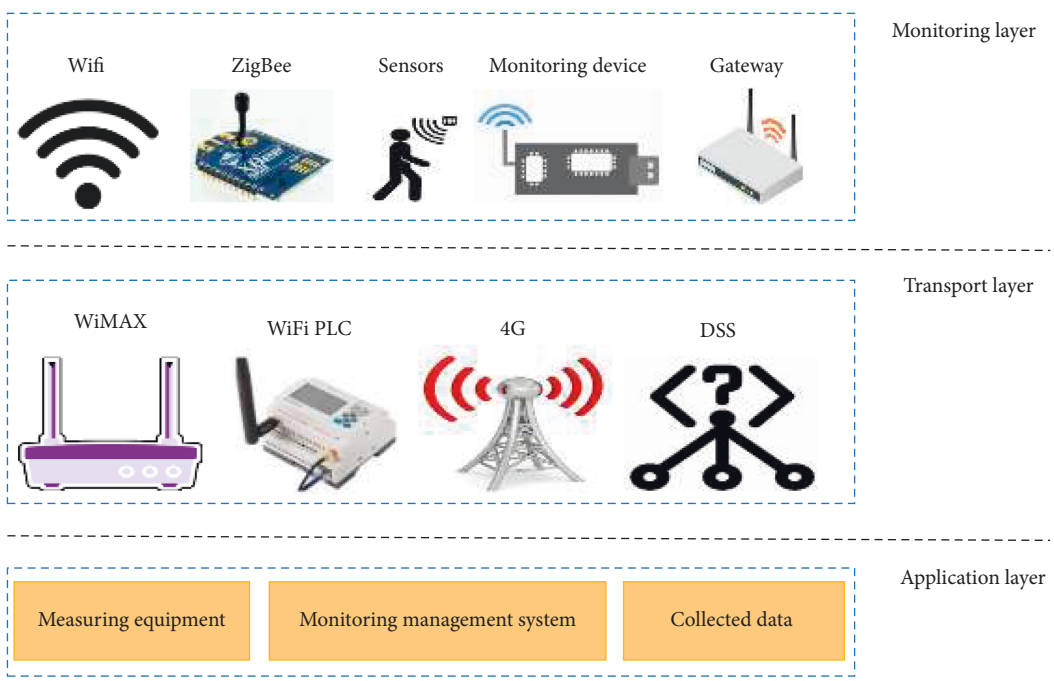

Figure 3: Architecture of a concert hall using wireless Internet of things system.

implement the monitoring device operation status, or send emergency commands to the device to control the device function.

4. Smart Concert Hall National Music System

The concert hall is the main venue for the performance of music programs. It can be divided into types according to the purpose of the concert hall, mainly professional concert halls and multipurpose concert halls. Most of the concert halls built in the 1990s were simple to use and could only be used for indoor and symphonic performances. Today, with the diverse growth of the market, firms from many business perspectives are constructing multipurpose concert halls, which should completely emphasize the local music peculiarities. They locate the concert hall as a national-oriented concert hall and design the concert hall's lighting system and music system. They employ lighting equipment to create a better stage environment in the concert hall. In this paper, the design of a smart concert hall starts from flexibility, switching simplicity, security, reliability, and storage, and the types of equipment configured in the system can undertake music performances of all nationalities. Reduce noise, lamp temperature, and so on to the greatest degree

possible while constructing the concert hall light system to fulfill the needs of the orchestra, symphony, chorus, and solo music, as well as to be able to record and transmit live.

4.1. Design the National Music System Module. This paper develops an intelligent concert hall national music system based on a neural network and wireless IoT and divides the system into two parts: front-end operation page and background operating system. The front-end page can complete the functions of charts, music management, popular recommendations, search tracks, user reviews, and my music. My music page is divided into two parts: recently played music and my music collection. There are two functions on the user review page: the latest comments and the popular comments. Figure 4 shows the function module of this system.

According to the above figure, the main function modules of the system background are comment management, song management, recommendation management, and user management. The system implicitly collects user behavior data for playing, downloading, and music collection. In addition, it uses a collaborative filtering recommendation algorithm based on neighbor users to recommend songs to users. If some national songs have different times, the similarity between songs can be analyzed by embedding network words based on heterogeneous text. According to the listening history of the national music of users, similar songs can be recommended. Furthermore, the system allows access to a user's access behavior and data records. A tag-based collaborative filtering algorithm may be used to propose music to users that are related to historical tags.

4.2. Recommendation Model Based on Music Attributes. There are many attributes of national music, which are usually used to define a better distinction between different music. The internal attributes mainly refer to the information of music beat, lyrics, sound quality, instruments, and sound quality. The external attributes include language, singer, style, and emotion. Music attributes have some objective attributes and some subjective attributes. Music genres and feelings can differ depending on who is listening, and user perceptions and preferences cannot be homogenized. The label, which comprises music emotion, style, and language, is another important outward aspect of music.

Here, five external attributes are selected to find out user attribute preferences, namely style, language, scene, theme, and emotion. These external attributes correlate to the dataset's music classification standards, and category information on different criteria may be acquired by utilizing the CURNN model to learn classification. By looking at the user's history of playing national music, we can see that each user's sensitivity to songs in different languages varies greatly, some prefer Mongolian music, and others prefer folk classics. For this feature, each user's preference for different music languages is calculated by the following equation:

$$\mathrm{MLP}_{ij} = \frac{\mathrm{musicLauguage}\left(U_i, L_j\right)}{\mathrm{musicCount}\left(U_i\right)}, \tag{5}$$

where $\mathrm{MLP}(U_i, L_j)$ refers to U_i users' preference for L_j language music, $\mathrm{music\,Language}(U_i, L_j)$ refers to users' listening to music in L_j J language in U_i history music, and $\mathrm{music\,Count}(U_i, L_j)$ refers to the number of music played.

According to this method, the user's scene preference (MNP), music style preference (MSP), theme preference (MTP), and emotion preference (MMP) can be calculated. The preference degree of music attribute is calculated through weighted calculation. It can be calculated by the following equation:

$$\begin{aligned} P_{i,j} = {} & l * \mathrm{MLP}_{i,j} + s * \mathrm{MSP}_{i,j} + n * \mathrm{MNP}_{i,j} \\ & + m\mathrm{MMP}_{i,j} + t * \mathrm{MTP}_{i,j}. \end{aligned} \tag{6}$$

In the above equation, we can calculate it as $l + s + n + m + t = 1$.

4.3. Weighted Hybrid Recommendation Model Based on Deep Learning. The hybrid recommendation method used in this paper needs to weigh two different models. Users often use the system to listen to songs, which will increase the weight of collaborative filtering. Less times of users' historical listening to songs will increase the weight of music attributes [23]. The recommendation degree of the weighted mixed music recommendation model is calculated by equation (7), and $\propto$ represents the weight.

$$\mathrm{Rec} = \propto \mathrm{sim} + (1 - \propto) P_{i,j}. \tag{7}$$

The basic process of weighted mixed recommendation is shown in Figure 5. The more the music labels, the better the recommendation effect. However, in most music libraries, the lack of music labels in varying degrees. The recommendation effect can be strengthened only after the missing music classification labels are supplemented. This paper uses the current neural network model to extract music features, label music types, and classification and to improve the music label classification on the music collection. Calculate the user's music attribute preference based on the music attribute recommendation model, and calculate the user similarity based on the collaborative filtering recommendation model. After completion, the top n recommendation list can be generated according to the preference and similarity of music attributes.

5. Performance Analysis of National Music System

5.1. Analysis of the Results of Recommendation Score of National Music System. In this paper, the national music system of the smart concert hall is developed based on a neural network and wireless IoT, and the national music system is applied in the concert hall. To better verify the effect of the music system, this paper uses the implicit scoring method to judge [24]. The selected data mainly come from the public

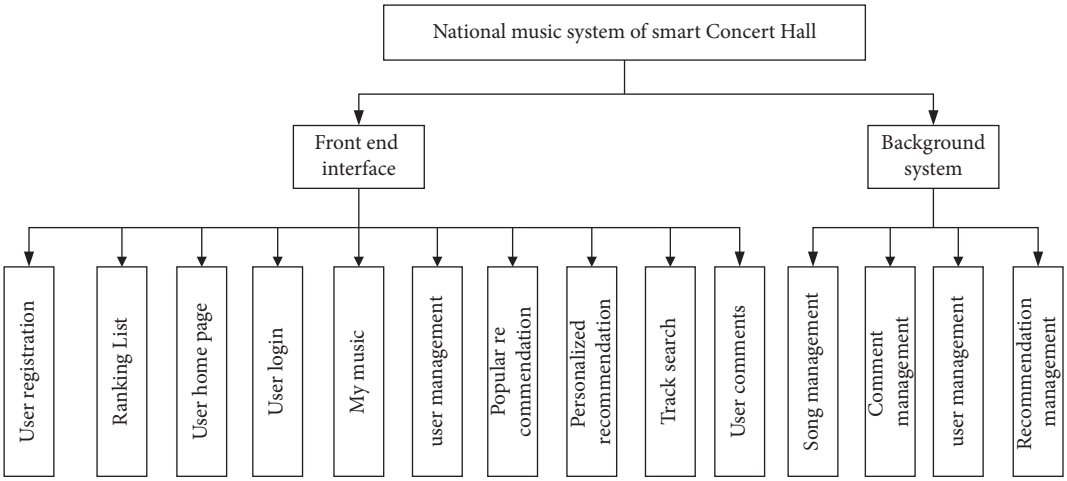

Figure 4: System function modules.

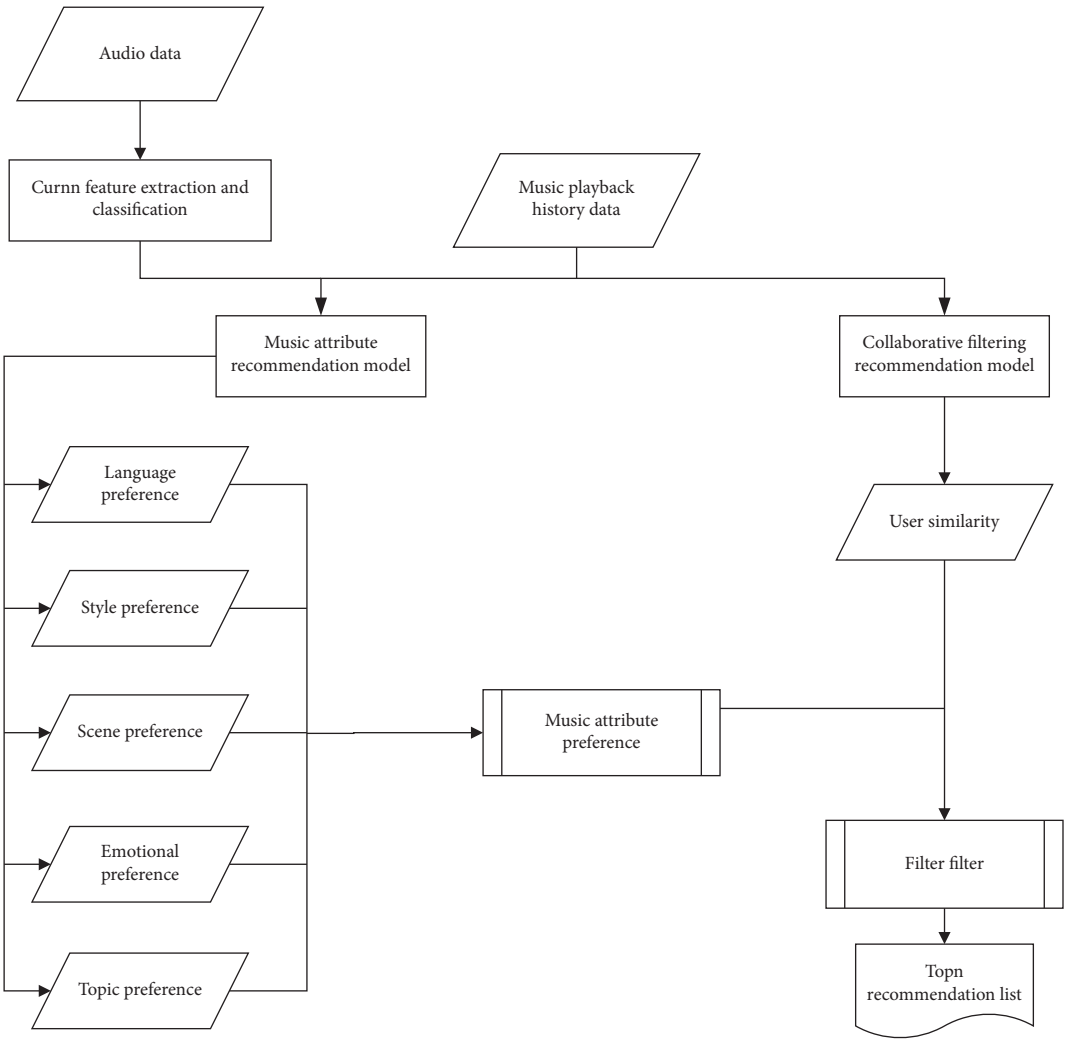

Figure 5: Hybrid recommendation process.

Table 1: Captured music data.

Data item	Quantity	Remarks
Music	245209	Music basic information and audio link
Music label	754683	Number of tags per music
User	798	User information
User label	2849	Different labels available to each user
Singer	11702	Singer information
Singer label	35698	Each singer's corresponding label
Song sheet	962	Song list information
Song list label	27954	Label corresponding to each song list
History of listening to songs	10000	The history of listening to folk music and songs repeatedly listened to by users

Table 2: Music classification in dataset.

Classification label	Classification details
Languages	Chinese, European and American, Arabic, French, Japanese, Cantonese
Style	Pop, dance music, light music, grassland, jazz, country, nationality, England
Scene	Morning, night, study, playing football, subway, driving
Emotion	Fresh, nostalgic, romantic, lonely, happy, missing and excited
Theme	Children, Internet songs, Internet, classics, variety show

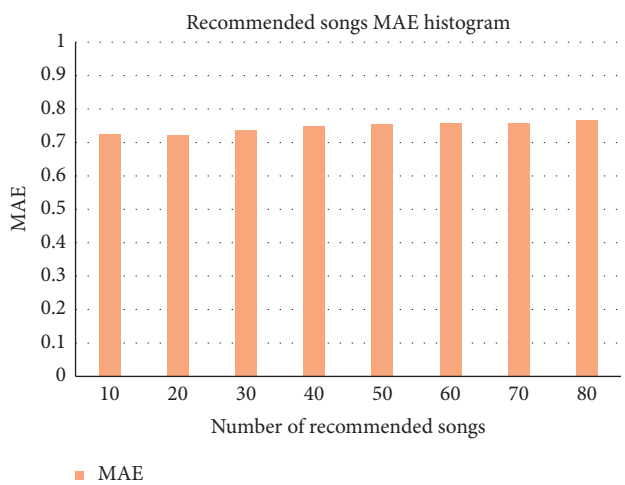

Figure 6: Recommended songs MAE histogram.

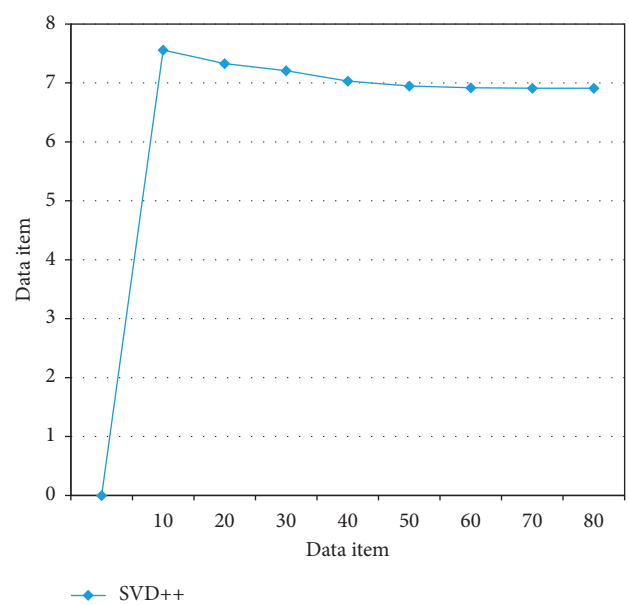

Figure 7: Comparison of 9 data items.

data on the Netease cloud. The national music data on the interface are captured through python data capture program, as shown in Table 1.

The classification standards of music labels in the data set mainly include style, language, scene, and language. The detailed classification contents of different classification indicators are listed in Table 2.

The system actively plays music once, downloads music, and collects a piece of music for 5 points. Combined with the data in Tables 1 and 2, the experimental results shown in Figure 6 are obtained.

According to the experimental results in the above figure, the average absolute error of MAE first decreases and then increases after increasing the number of recommended national music songs. When the number of recommended national music songs is 20, the lowest Mae value is 0.73. When the number of recommended national music songs exceeds 20, the MAE value increases rapidly. As the number of suggested folk music songs grows, so does the number of needed scores. Furthermore, the results produced in this experiment are consistent with people's fundamental cognition when the system error rate increases.

5.2. Analysis of Recommendation Results of National Music System. This paper develops an intelligent concert hall ethnic system based on a neural network and wireless IoT. The music attribute model, collaborative filtering model, mixed model, K-means model, SVD++ model, MAE (average absolute deviation), and RMSE evaluation models are created to examine the efficacy of this system [25]. Using this index to evaluate the effect of music physical examination, RMSE is

Table 3: Comparison results of recommended models.

Number of music	SVD++ (MAE)	SVD++ (RMSE)	K-means (MAE)	M-means (MAE)	Hybrid model (MAE)	Hybrid model (RMSE)
10	7.56	10.69	8.37	10.45	7.25	9.76
20	7.33	10.32	8.02	10.12	6.91	9.65
30	7.21	10.24	7.61	10.05	6.85	9.49
40	7.03	10.12	7.35	10.04	6.78	9.35
50	6.95	10.03	7.12	10.01	6.76	9.29
60	6.92	6.95	7.06	9.88	6.74	9.18
70	6.91	9.93	6.99	9.74	6.73	9.13
80	6.91	9.81	6.91	9.71	6.69	9.09
90	6.85	9.58	6.85	9.67	6.66	9.04
100	6.81	9.44	6.81	9.25	6.65	8.97

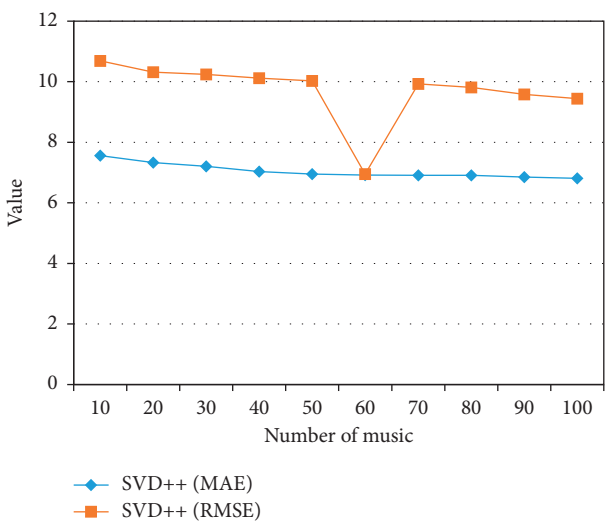

Figure 8: Comparison between SVD++(MAE) and SVD++(RMSE).

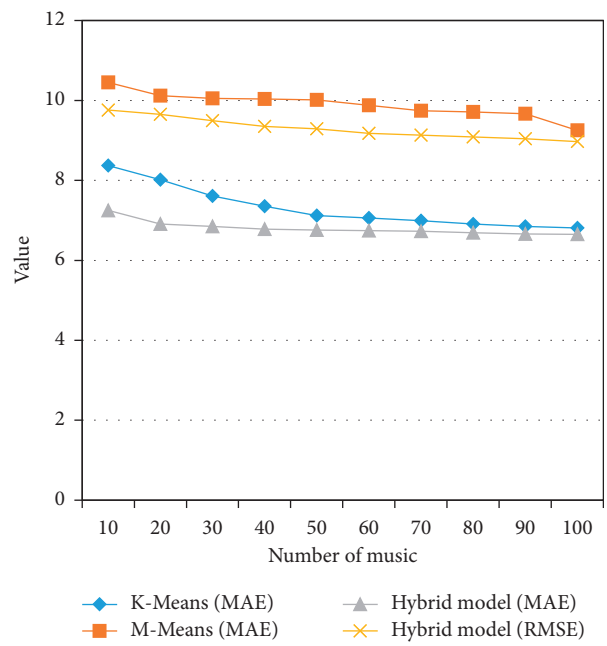

Figure 9: Comparison among 4 models.

the root mean square error. By using this index, we can evaluate the dispersion of music recommendation results.

If the predicted user's score set for n music is $P = \{P_1, P_2, P_3, \ldots, P_n\}$, the user's true score set for n national music is $R = \{R_1, R_2, R_3, \ldots, R_n\}$, and the MAE is calculated using the following equation:

$$\mathrm{MAE} = \frac{\sum_{i=1}^{n} |P_i - R_i|}{n}. \tag{8}$$

Calculate RMSE from the following formula:

$$\mathrm{MAE} = \sqrt{\frac{\sum_{i=1}^{n} (P_i - R_i)^2}{n}}. \tag{9}$$

The EaseSong dataset built in this paper has a total of 800 users and stores up to 25,000 pieces of music. It divides all music into three subsets for i users, represented by D_{1i}, D_{2i}, and D_{3i}. Here, D_{3i} is the national music collection that i users have not heard, the mutually exclusive collection of national music that users have heard is represented by D_{1i} and D_{2i}, D_{1i} is the training set, D_{2i} is the testing set, and the number of national music stored in D_{1i} is about twice as large as that in D_{2i} i.

Figure 7 shows the data comparison of 9 data items. According to this figure, the highest quality among these data items is the music label, which is 754683 (no. of tags per music). On other hand, the smallest quantity is the user (only 798 user information).

The experimental results show that the MAE and RMSE values of the mixed model are lower than those of other models, and the recommended results are satisfactory. The RMSE and MAE values decreased significantly after continuously increasing the number of prediction scores. Only the results between the three music models are listed in Table 3, which fully demonstrates that the model recommendation works well.

The analysis of the experimental results in Table 1 shows that the MAE predicted by the hybrid model is lower than that of the other two models, so it can be concluded that the recommended effect of the hybrid model is more ideal [26].

The mean absolute error (MAE) is a linear rating, which indicates that all individual variances in the average are weighted proportionally. The root-mean-square mistake

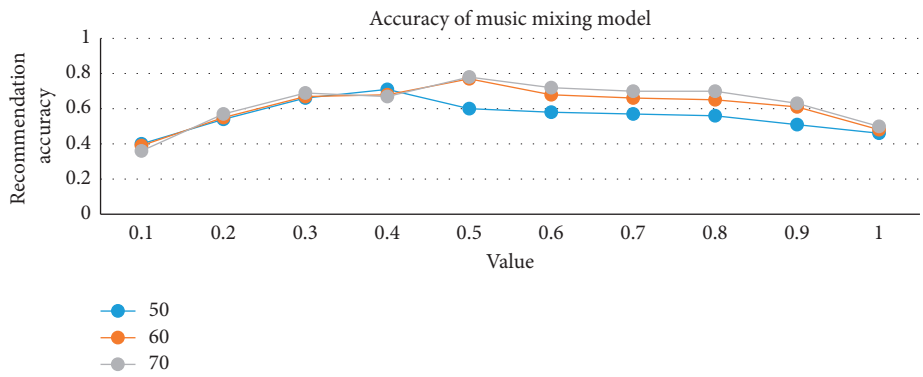

Figure 10: Variation of the accuracy of music mixing model with $\propto$ value.

(RMSE) is a quadratic scoring mechanism that calculates the average size of an error. Figure 8 shows the comparison between SVD++(MAE) and SVD++(RMSE) for the number of music. According to this figure, the MAE for 10 music is the greatest (such as 7.56), and the MAE for 100 music is the lowest (such as 6.81).

Figure 9 compares K-means (MAE), M-means (MAE), hybrid model (MAE), and hybrid model (MAE) (RMSE). According to this figure, the outcome of my suggested model is good, demonstrating the model's correctness.

The national music system of the smart concert hall developed in this paper has great changes in the accuracy of the model according to different weight values, as shown in Figure 10. In this paper, by processing the EaseSong data crawled by the system, the processing results show that 60 songs heard by users are the median. Therefore, 50, 60, and 70 songs heard by users are selected for experiments to judge the impact of value difference on accuracy. The experimental results show that after the number of songs continues to increase, the accuracy of the model also continues to increase. If it is 50 songs and the value of $\propto$ is 0.4, the recommended accuracy is the highest. If the number of songs is 60 and $\propto$ is 0.5, the recommendation accuracy is the highest. If the number of songs is 70 and $\propto$ is 0.6, the recommendation accuracy is the highest. Therefore, the validity of the music recommendation model of the system is tested. When users listen to a large number of folk music songs, they can improve the weight of the collaborative filtering model. When the number of songs is small, the weight of the music attribute model is low, so they can get a better recommendation effect.

6. Conclusions

With the rapid development of science and technology, all fields are moving towards intelligence. The single music mode of a traditional concert hall cannot meet people's basic needs. More and more people expect to build a smart concert hall, which can perform national music. For this demand, this paper adopts the most advanced neural network algorithm and combines it with the wireless IoT to develop and establish the national music system of the smart concert hall. By constructing the architecture model of the wireless IoT system in the concert hall, complete the development of the intelligent music ethnic system, and introduce the functional modules of the system. Combined with the music attribute recommendation model and the weighted hybrid recommendation model based on deep learning, realize the recommendation function of the ethnic music system. To verify the application effect of the system, the scoring analysis of the system shows that when the number of folk music songs recommended by the system is less than 20, the minimum MAE is 0.73, and the MAE value continues to rise after the number of folk music recommended exceeds 20.

Data Availability

All the data are available in this paper as part of the publication.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Construction of Sports Training Management Information System Using AI Action Recognition

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With the development of science and technology, more and more fields have begun to use AI to provide convenient services for humans. Artificial intelligence (AI) refers to a new technology that uses human thinking to respond accordingly through computers and robots to assist human beings. Action recognition is an important research project that needs to be broken through in many industries, such as security system, martial arts instruction, and dance training. This paper aims to study a method for action recognition using AI technology and to build a sports training management information system. In this paper, a recognition model and related algorithms using a convolutional neural network (CNN) are proposed, and an intelligent sports training management information system is constructed. The system and the model are tested, the action recognition effect of 60 athletes in a university is tested, and the comparison with the traditional recognition algorithm is carried out. The results show that the CNN recognition accuracy test results used in this paper are generally more than 90%, while the traditional recognition accuracy rate is only about 75%, and the highest is not more than 86%; the training management information system of this paper takes about 15.7 s, and the maximum time is not more than 10 s, while the traditional recognition system takes about 15.7 s, which is about twice the time of the system in this paper. Therefore, it shows that the CNN recognition method in this paper has a significantly better effect on the recognition of athletes' movements, and the sports training management information system constructed in this paper is less time-consuming and faster and has certain feasibility.

1. Introduction

Human action recognition is an important and challenging topic in computer vision. Recently, CNN has established impressive results for many image recognition tasks. CNN typically contains millions of parameters that are prone to overfitting when trained on small datasets. Therefore, CNN does not yield better performance than traditional action recognition methods. Additionally, sparsity has been shown to be one of the most important properties for visual recognition purposes. Adaptive sparse coding is used to capture high-level patterns from the data.

Human motion recognition plays an increasingly important role in many fields such as smart home, human-computer interaction, patient monitoring system, medical, and health care and can be applied to many aspects such as public places, medical care, and security. With the advent of the era of big data, the continuous increase in the amount of data such as various media interactions and chat software has generated a large amount of information about human movements, and the recognition of human movements in videos faces great challenges.

With the boom of low-cost and easy-to-operate depth cameras, neural network-based human action recognition has been extensively studied recently. However, most existing methods partially consider all 3D joints of the human skeleton to be the same. In fact, these 3D joints exhibit different responses to different action categories, and certain joint configurations are more discriminative for distinguishing specific actions.

The traditional CNN structure can maintain a certain degree of translation and rotation invariance for a specific

position in space for the input image. This spatial invariance only acts on the local area of the input image, and the entire image cannot achieve the invariance of the overall spatial rotation in the stacked local area. Since the pooling layer in the CNN structure has many limiting factors, for example, when extracting features, a lot of useful information is lost, the input data are only a local operation, and the feature map in the middle of the CNN framework will produce large distortions and will make it difficult for CNN to achieve spatial transformations such as rotation and scaling of images. The feature map generated in the process of CNN extracting features is not an overall transformation of the input data and is more restrictive. At the same time, there are large intraclass differences between the categories of human actions, and different people may perform a class of actions with great differences in amplitude and frequency. And there may be big differences in body size between different people. Human movements cannot be completed in one frame.

With the development of technology, the previous methods can no longer meet the current environment. The innovation of this paper is to propose a three-dimensional CNN recognition algorithm model, which can recognize athletes' movements more quickly and accurately. And the test results of this paper are compared with the traditional identification methods, the data are more intuitive, and the results are more obvious.

2. Related Work

Regarding action recognition technology, many scholars have carried out related research on it. Fanello et al. proposed the use of linear support vector machines for simultaneous online video segmentation and action recognition and showed that sparse representations play an important role in enabling one-shot learning and real-time action recognition. The main contribution of his research was an efficient real-time action modeling and recognition system; the paper highlighted the effectiveness of sparse coding techniques in representing 3D actions [1]. The aim of Nakonechna et al.'s study was to estimate the distribution of phosphatidylserine in the phospholipid bilayer of the liver membrane and the apoptotic stage of rat hepatocytes under the influence of surfactants: ethylene glycol (EG), polyethylene glycol 400 (PEG-400), and polypropylene glycol (PPG). Nakonechna et al. utilized the specific signals of macrophages to specifically recognize and eliminate apoptotic cells [2]. Yu and Yun presented a novel method, which was called the maximum margin heterogeneous information machine (MMHIM), for human action recognition from RGB-D videos. MMHIM fuses heterogeneous RGB visual features and depth features and uses the fused features to learn an efficient action classifier. Rich heterogeneous vision and depth data are efficiently compressed and projected into shared spaces and independent private spaces for learning to reduce noise and capture useful information for identification. Knowledge from various sources can then be shared with others in the learning space to learn cross-modal features [3]. Yanhua et al. put forward a discriminative multiinstance multitask learning (MIMTL) framework to discover intrinsic connections between joint configurations and action classes. Yanhua conducted extensive evaluations on MIMTL using three benchmark 3D action recognition datasets. Experimental results showed that the MIMTL framework proposed by Yanhua had good performance compared with several state-of-the-art methods [4]. However, these action recognition methods are more traditional and can only be used for single human action recognition and are difficult to apply multiple recognition objects and complex environments.

In order to be applicable to the complex environment and the situation of multiple recognition objects, some scholars have proposed new recognition methods. Nguyen et al. proposed a new method for action recognition based on Gaussian descriptors. Experimental evaluations showed that the method achieved very promising results on all datasets [5]. Xiu-Hong et al. used UPLC-MS technology and the pattern recognition method to study the potential biomarkers of endometriosis in rats with cold blood coagulation and blood stasis (ECB) and the effective mechanism of paeoniflorin (PF) [6]. Yu et al. designed a novel two-stream fully convolutional network architecture for action recognition, which can significantly reduce parameters while maintaining performance [7]. Although these methods can be adapted to multitarget recognition and complex environments, the recognition efficiency is not high, and the recognized results are not ideal, so it is necessary to further improve.

3. AI-Based Action Recognition Method

3.1. AI-Based Action Recognition. Artificial intelligence (AI for short) is an intelligent technology that simulates the human brain for thinking operations and has been widely used in many fields. With the influx of AI research, AI-related applications such as smart sweeping robots, smart speakers, personal assistants, and face-scanning payments are gradually appearing in people's lives [8, 9]. AI research is almost ubiquitous in people's lives, and related research is being carried out in various fields such as finance, medical care, autonomous driving, and education, as shown in Figure 1. Heavy scientific and engineering calculations are originally undertaken by the human brain. Today, AI can not only complete this calculation but also do it faster and more accurately than the human brain. Therefore, contemporary people no longer regard this kind of computing as a "complex task that requires human intelligence to complete." It can be seen that the definition of complex work changes with the development of the times and the advancement of technology, and the specific goals of the science of AI also naturally develop with the changes of the times.

AI includes a variety of science and technology, as shown in Figure 2. Machine learning is a core technology of AI, and neural network is the most important algorithm of machine learning. At present, for action recognition, CNN neural network has unique advantages in action recognition due to its convolution principle [10, 11]. Machine learning is a multidomain interdisciplinary subject involving probability

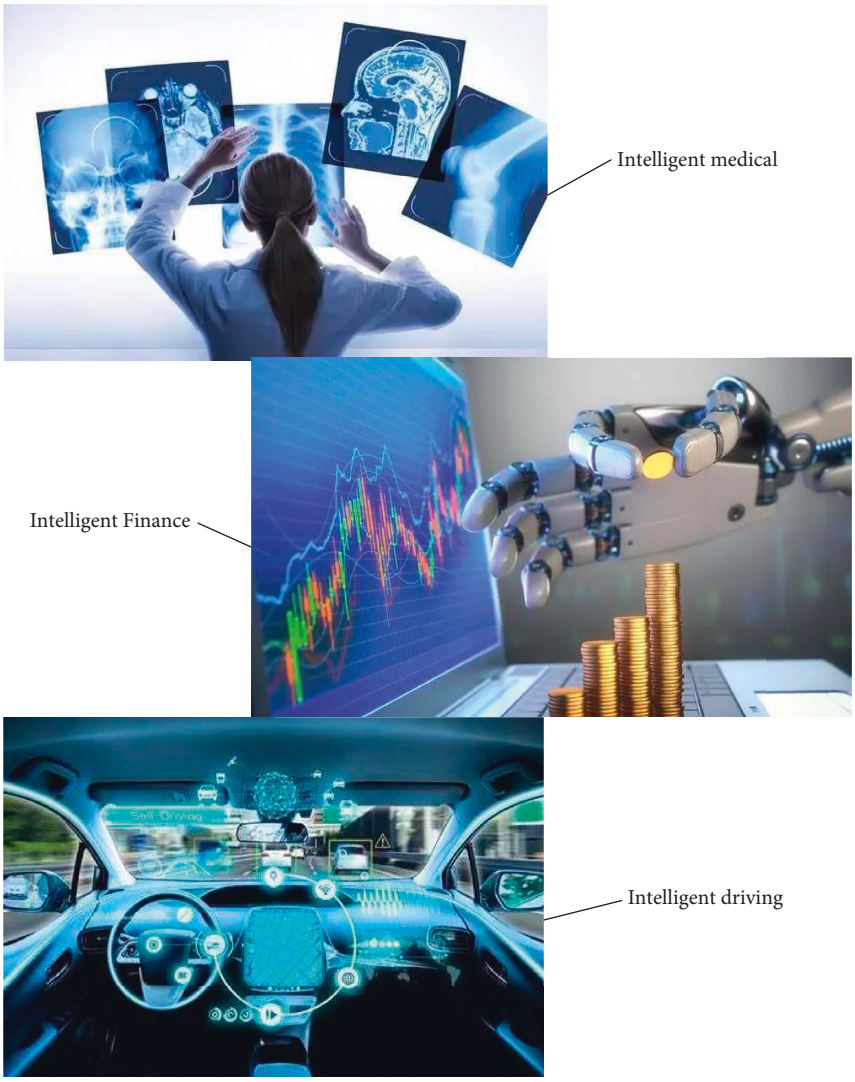
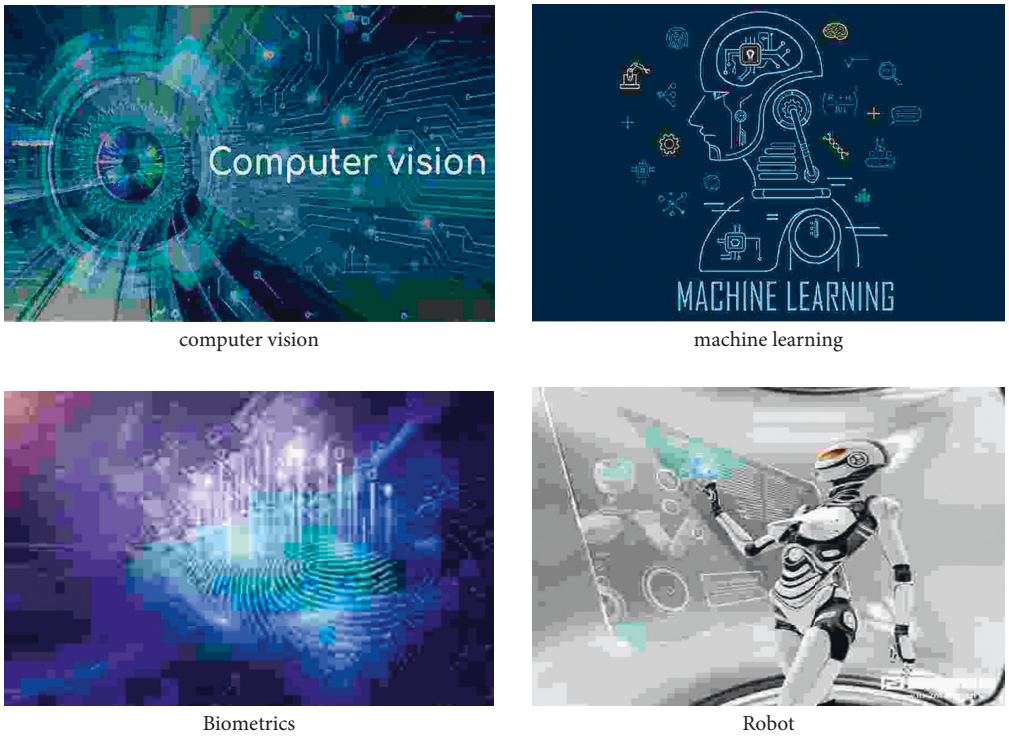


Figure 1: AI application areas.

theory, statistics, approximation theory, convex analysis, algorithm complexity theory, and other disciplines. It specializes in how computers simulate or realize human learning behaviors to acquire new knowledge or skills and reorganize existing knowledge structures to continuously improve their performance.

3.2. Neural Networks. 3D CNN is the most popular method used in human action recognition tasks. Figure 3 shows an example of a 3D CNN, where a typical 3D CNN consists of multiple layers of basic structures stacked. Each basic structure includes a 3D convolutional layer, a batch normalization layer, an activation layer, and a 3D pooling layer. If it is used for human action recognition tasks, the input of the network is a video frame cube composed of video frames intercepted from the original video, and a fully connected layer and a classification layer will be added at the end of the network [12, 13]. The approximate calculation process of 3D CNN is that the video frame cube is input from the input layer; the 3D convolution layer convolves the input feature cube with a 3D convolution kernel to obtain the output feature cube; the batch normalization layer roughly normalizes the pixel values of the output feature cube into a distribution with 0 mean and unit variance; the output feature cube is subjected to the nonlinear transformation of the activation function of the activation layer to obtain the activated feature cube; the three-dimensional pooling layer performs three-dimensional pooling operation on the activated feature cube to reduce the size of the feature cube; the fully connected layer further learns the features; the classification layer obtains the probability of each category [14].

The core part of the 3D CNN is the 3D convolution operation, which is also the most computationally intensive part of the entire network. The convolution process is shown in Figure 4. The input of the 3D convolution operation is the input feature cube and the 3D convolution kernel, and the output is the output feature cube. The input feature cube in the first layer refers to the first input video frame cube. The middle layer refers to the output of the previous layer. Generally speaking, feature cubes are multichannel, which means that in addition to the height, width, and depth



computer vision machine learning

Biometrics Robot

Figure 2: AI core technology.

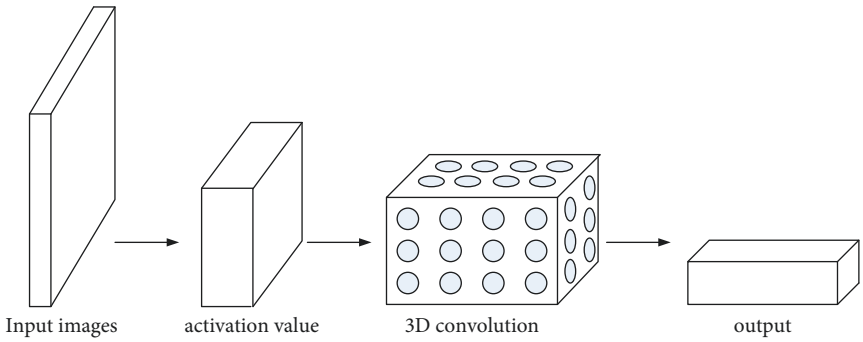


Figure 3: Schematic diagram of CNN.

dimensions of the feature cube itself, there are also channel dimensions. The 3D convolution kernel is a feature extractor used to extract features in the input feature cube, which also has four dimensions. Its height, width, and depth dimensions are smaller than the corresponding dimensions of the input feature cube, but the fourth dimension is equal to the number of channels of the input feature cube. Its parameters, called kernel weights, can be trained to make it a better feature extractor [15, 16]. The output feature cube is the extracted features. The process of extracting features is convolution, and the convolution is similar to the convolution in the field of digital signal processing, but it is not the same [17].

The size of each dimension of the output feature cube of the 3D convolutional neural network will be reduced according to the multiple of the corresponding dimension size of the pooling cube. Usually, the three dimensions of the pooling cube are all 2, so the size of each dimension of the output feature cube after pooling is generally one-half of the input feature cube. The pooling operation is similar to the convolution operation, in which a small cubic filter slides on the input feature cube to obtain the output feature cube. However, the sliding step size during pooling is usually the side length of the pooling cube, and the small cube filter during single pooling and the part of the input feature cube framed by it are not multiplication and accumulation calculations performed. Instead, the average or maximum value is calculated according to the different pooling methods [18].

Grouped convolutions can also reduce computation like depthwise separable convolutions. However, it avoids the shortcomings of the depthwise separable convolution and does not increase the binary activation operation at the algorithm level, nor does it increase the memory access operation at the hardware implementation level. Not only

that but it also has a big advantage at the hardware implementation level. Since its convolution is only performed within each group, the addition between channels is also performed only between channels within each group. Therefore, the pixel value range of its output feature map will be reduced by the number of groups, which will greatly reduce the consumption of storage resources. Despite these advantages, grouped convolution also has its disadvantage, which is the problem of poor information flow between groups as explained earlier. However, this shortcoming can be eliminated by using the channel rearrangement method at low cost, so this paper uses grouped convolution for lightweight design [19, 20].

This paper firstly analyzes the most widely used depthwise separable convolution method, which is characterized by decomposing conventional convolution into two steps: channel-by-channel convolution and point-by-point convolution. The advantage is that the number of multiplication calculations of convolution is reduced. Although it works well in real-valued CNN, it is not suitable for the algorithm model of this paper. Because the algorithm model in this paper has a binary activation operation before each convolution calculation, the depthwise separable convolution is used. It divides one layer of convolution into two and changes the binary activation operation into two, and more activation operations will bring about the loss of information. In particular, the value range of the output of the binary channel-by-channel convolution is small because there is no addition between channels. That is to say, the included feature information is relatively weak, and the subsequent insertion of a binary activation will make the feature information weaker. This part is the analysis from the perspective of the algorithm. From the perspective of hardware implementation, the depthwise separable convolution method is not suitable for this study. The purpose of hardware implementation is to use the parallel computing characteristics of hardware to make neural network computing faster, but not infinitely stacked computing units can accelerate infinitely. This is because the computing speed is also limited by the speed of the data supply; that is, it is limited by the storage bandwidth. Therefore, in order to design the operation of a hardware-accelerated neural network, both computing unit design and memory access mode must be taken into account.

The research of this paper not only stays at the algorithm level but also designs its dedicated hardware accelerator for the proposed algorithm. Because it involves the design of the hardware circuit, the design of the algorithm model should not only consider the performance of the algorithm but also consider the consumption of logic resources such as gate units, flip-flops, and on-chip storage when the algorithm is implemented in hardware. The binary CNN model can well meet these requirements, and it not only greatly reduces the storage requirements but also has no multiplication calculation. It is a hardware-friendly CNN model, so the algorithm model in this paper also adopts binarization technology. The difference between the convolution operation in the binarization technique and the conventional convolution operation is that its input has only two values of -1 and 1. In this case, the multiplication calculation in the conventional convolution can be simplified to the XNOR calculation in the logical operation, and the addition calculation can be simplified to the bit count calculation. The result of the binary convolution is not a single bit, but some integers with a small range of values can be represented by a small number of bits, which is why the binary activation operation is used to binarize it again later.

4. CNN Action Recognition Sports Training Management Information System

4.1. CNN Computational Model. The CNN structure is shown in Figure 5. The convolution operation includes continuous and discrete convolution. For continuous convolution, the calculation is

$$y(t) = \int_{-\infty}^{\infty} x(p)h(t-p)dp = x(t) * h(t). \tag{1}$$

The calculation for discrete convolution is

$$y(n) = \sum_{i=-\infty}^{\infty} x(i)h(n-i) = x(n) * h(n). \tag{2}$$

Additionally, 2D convolutional feature extraction is calculated as

$$v^{xy} = \sum_{p=0}^{P-1}\sum_{q=0}^{Q-1} w^{pq} u^{(x+p)(y+q)}. \tag{3}$$

The 3D convolutional feature extraction is calculated as

$$v^{xyz} = \sum_{p=0}^{P-1}\sum_{q=0}^{Q-1}\sum_{r=0}^{Q-1} u^{(x+p)(y+q)(z+r)} w^{pqr}. \tag{4}$$

The sampling of 2D graphics can be expressed as

$$y_{mn} = \frac{1}{S_1 S_2}\sum_{j=0}^{S_2-1}\sum_{i=0}^{S_1-1} x_{m\cdot S_1+i, n\cdot S_2+j}. \tag{5}$$

S is the figure size, y is the output, and x is the input.

The maximum sampling of 3D video can be expressed as

$$y_{mnl} = \max_{i,j,k;S_1,S_2,S_3}\left(x_{m\cdot S_1+i, n\cdot t+j, l\cdot r+k}\right). \tag{6}$$

The back-propagation process of the convolutional neural network is shown in Figure 6, in which the loss function is introduced.

$$J(W,b;x,y) = \frac{1}{2}\left\|h_{W,p}(x) - y^2\right\|. \tag{7}$$

where W, b represents the weight of the CNN.

For a dataset with m samples, the loss function is

$$J(W,b) = \left[\frac{1}{m}\sum_{i=1}^{m} J\left(W,b;x^i,y^i\right)\right]. \tag{8}$$

The way to update the weights using the gradient descent method (gradient descent is a first-order optimization

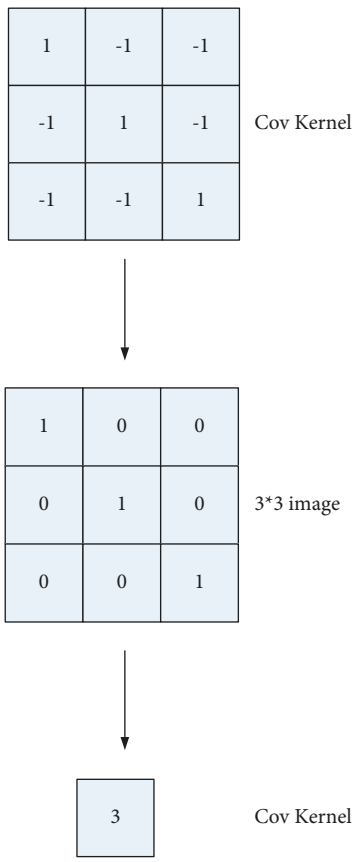


Figure 4: CNN convolution operation.

algorithm, also commonly known as steepest descent. To find the local minimum of a function using gradient descent, an iterative search must be performed to a point at a specified step distance in the opposite direction of the gradient corresponding to the current point on the function.) is

$$W_{ij}^{l} = W_{ij}^{l} - \alpha \frac{\partial}{\partial W_{ij}^{l}} J(W, b),$$
$$b_{i}^{l} = b_{i}^{l} - \frac{\partial}{\partial b_{i}^{l}} J(W, b). \tag{9}$$

For the n_l-th layer network, the residuals of each node are

$$\delta_{i}^{n_l} = \frac{\partial}{\partial Z_{i}^{(n_l)}} \frac{1}{2} y - h_{w,b}(x)^{2}. \tag{10}$$

The residual for the i-th neuron node of the l-th layer is

$$\delta_{i}^{l} = \left(\sum_{j=1}^{S_{l+1}} W_{ji}^{l} \delta_{j}^{l+1} \right) f'\left(z_{i}^{l}\right), \tag{11}$$

where z_i^l is the weight increment.

From this, the partial derivatives of the loss function and the nodes and biases of each layer can be obtained.

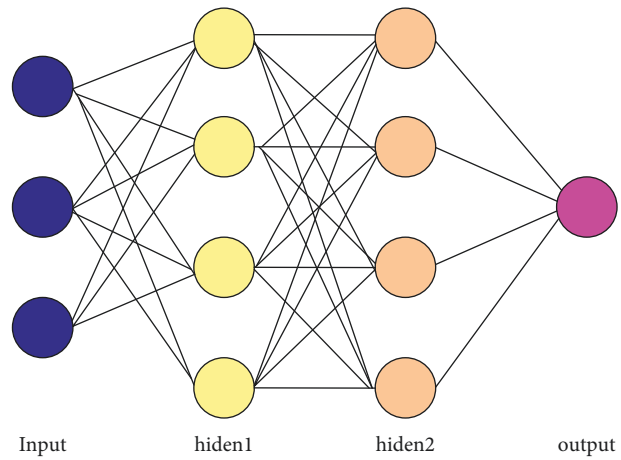


Figure 5: CNN network structure.

$$\frac{\partial}{\partial W_{ij}^{l}} J(W, b; x, y) = a_{j}^{l} \delta_{i}^{l+1},$$
$$\frac{\partial}{\partial b_{i}^{l}} J(W, b; x, y) = \delta_{i}^{l+1}. \tag{12}$$

After the identification and fusion of the graphics, the regression analysis is carried out. In this paper, the softmax regression model is selected, and its expression is

$$h_{\theta}\left(x^{i}\right) = g\left(\theta^{T} x^{i}\right) = \frac{1}{1 + e^{-\theta^{T} x^{i}}}. \tag{13}$$

(x, y) represents the sample training set.

With the training parameter θ, the loss function is calculated

$$J(\theta) = -\frac{1}{m} \left[\sum_{i=1}^{m} y_i \log h_{\theta}\left(x^{i}\right) + \left(1 - y^{i}\right) \log\left(1 - h_{\theta}\left(x^{i}\right)\right) \right]. \tag{14}$$

Let h_θ be

$$h_{\theta}\left(x^{i}\right) = \frac{1}{\sum_{j=1}^{k} e^{\theta^{T} x^{i}}}. \tag{15}$$

Then, the training model is iteratively calculated, and the gradient can be obtained by derivation

$$\nabla_{\theta_j} J(\theta) = -\frac{1}{m} \sum_{i=1}^{m} \left[\left(x^{i} 1\left\{ y^{i} = j \right\} - p\left(y^{i} = j | x^{i}; \theta \right) \right) \right]. \tag{16}$$

$\nabla_{\theta_j} J(\theta)$ represents the partial derivative value.

The update method of the parameters is

$$\theta_j = \theta_j - \alpha \nabla_{\theta_j} J(\theta). \tag{17}$$

The loss function is updated to

$$J(\theta) = -\frac{1}{m} \left[\sum_{i=1}^{m} \sum_{j=1}^{k} 1\left\{ y^{i} = j \right\} \log \frac{e^{\theta^{T} x^{i}}}{\sum_{j=1}^{k} e^{\theta^{T} x^{i}}} \right] + \frac{\lambda}{2} \sum_{i=1}^{m} \sum_{j=1}^{k} \theta_{ij}^{2}. \tag{18}$$

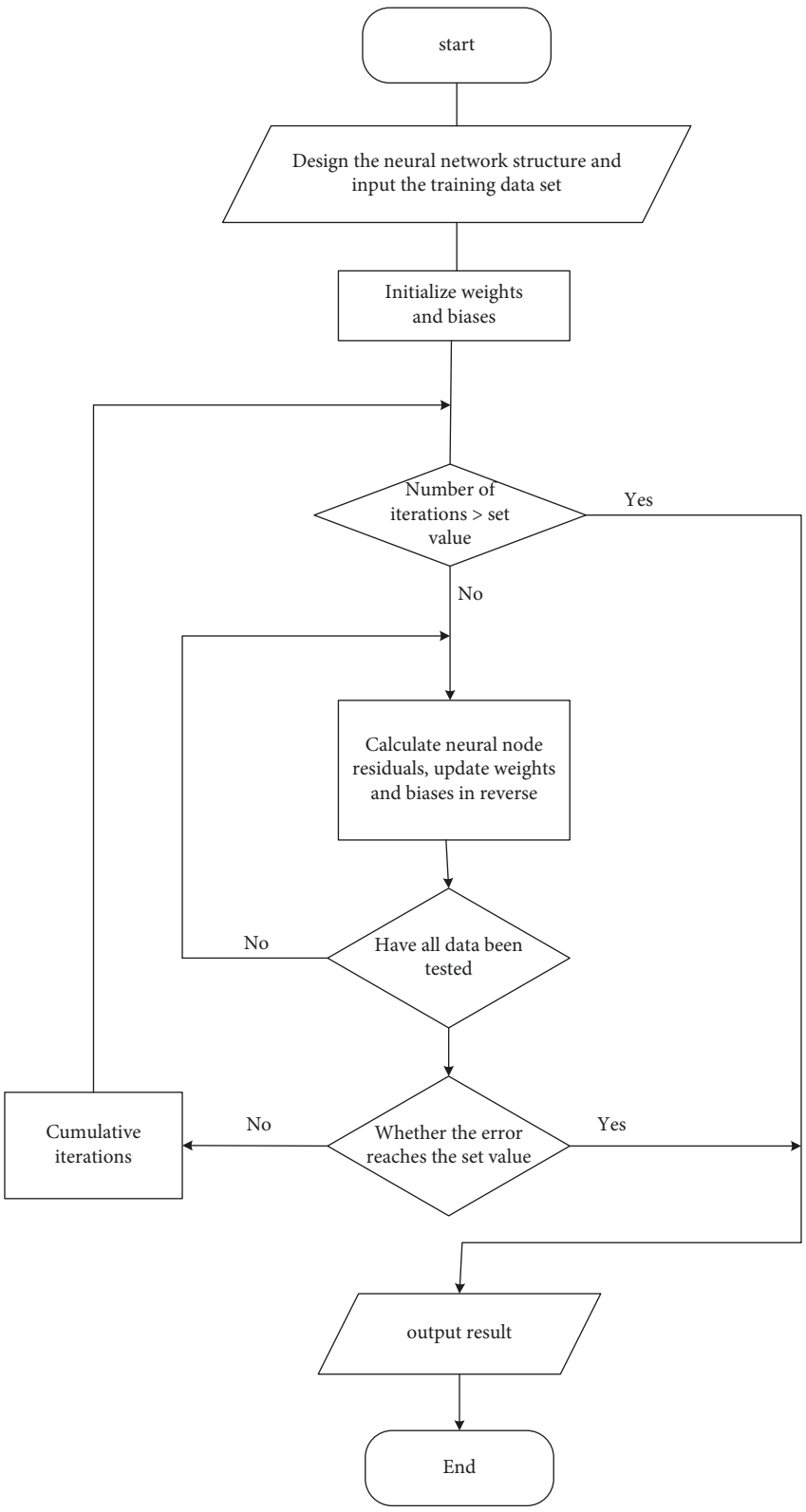


Figure 6: CNN back-propagation process.

After filtering the term, it is transformed into a convex function of the optimal solution, and the derivative of it can finally be obtained

$$\nabla_{\theta_j} J(\theta) = -\frac{1}{m}\sum_{i=1}^{m}\left[x^i\left(1\left\{y^i = j\right\} - p\left(y^i = j|x^i;\theta\right)\right)\right]. \quad (19)$$

Finally, $J(\theta)$ is minimized, and the softmax regression model (the softmax logistic regression model is a generalization of the logistic regression model for multi-classification problems. In a multiclassification problem, the class label y can take more than two values. Softmax regression models are useful for problems such as MNIST handwritten digit classification, where the goal is to identify 10 different single digits) is obtained, and then, the classification and recognition of actions are realized.

4.2. Experimental Design

4.2.1. Management System. The sports training management system designed in this paper is shown in Figure 7, and its objects mainly include athlete, referee, and planner.

In this paper, the research at the level of the 3D CNN algorithm is carried out from the perspective of reducing the data bit width of the network and reducing the amount of network computation. Binarization and lightweight techniques are applied to optimize the design of 3D CNN. In order to pave the way for the next hardware accelerator design at the algorithm level at the cost of a slight loss of recognition accuracy, a hardware accelerator with less resource consumption, lower power consumption, and faster speed can be designed. The research content of this paper at the level of 3D CNN hardware accelerator design is to design its dedicated hardware accelerator for the algorithm model of this paper. On the premise of correct function, it can achieve a high processing frame rate and high computing energy efficiency, in order to use it to build an action recognition system with practical use value.

4.2.2. Training Method. Untrained CNN cannot be used directly, because the initialization parameters of CNN do not have the ability to extract features from the input, so its output has no value. The back-propagation algorithm is now used for training. Back-propagation is a method that uses the chain rule to obtain the gradient of the parameters of each layer of the network layer by layer. After the gradient is obtained, each parameter is updated based on it. The continuous cycle of forward propagation and back propagation can gradually update the parameters to obtain parameters with better feature extraction ability. The whole process is training. At present, there are some back-propagation optimization algorithms that can make the training effect better, among which the SGD algorithm is often used. The difference between it and the original BP algorithm is that the SGD algorithm only selects a small batch in the training set to calculate the gradient instead of selecting the entire training set to calculate the gradient like the original BP algorithm. The SGD algorithm with momentum is an improvement to SGD. Unlike SGD, it not only uses the gradient of the currently calculated mini-batch to update the weight but also uses the gradient of the training set that has been calculated to update the weight. Before constructing the 3DCNN structure, the grayscale features, motion features, and edge features have been extracted by the operations of the training samples, as shown in Figure 8.

4.2.3. Channel Rearrangement. The channel rearrangement operation is usually used in conjunction with the grouped convolution. It reorders the output feature maps in each group after the grouped convolution operation according to certain rules, just like shuffling cards, so it is called channel rearrangement. The meaning and specific operation of channel rearrangement will be described with reference to Figure 8, and various input feature data are exemplified in the figure. In order to solve the problem of poor information exchange, the output feature maps of the first grouping convolution can be scrambled and reassigned to each group of inputs of the second grouping convolution operation. In this way, each group of inputs of the second grouped convolution will contain the information of each group of the previous first grouped convolution. Then, the output of each group after the second grouping convolution will contain the information of the first three groups of feature maps input, and the information will flow smoothly among the groups.

Normalization: 0/1 binary convolution brings many benefits, but it introduces a new problem compared to −1/+1 binary convolution. Then, the value range of the output of the 0/1 binary convolution is greater than or equal to 0, and the pooling operation will not change the value range. Directly using this as the input for the next binary activation will result in 0 as the threshold. All outputs of the step function for binary activation are 1. Obviously, such binarization is incorrect. In order to solve this problem, the batch normalization operation in the conventional CNN can be added before the binary activation, and the input of the binary activation can be roughly normalized into distribution with 0 as the mean and 1 as the variance. In this way, the output of the binary activation will have both 0 and 1. But in the binary network, the purpose of normalization is only to change the input of the binary activation into a distribution of 0 mean value to cooperate with the subsequent binary activation, so it is only necessary to introduce the mean value for calculation. Even if the variance term is introduced, since the value of the denominator formed by the variance term is always positive, dividing by a positive number will not change the positive or negative nature of the result, which means that it has no effect on the result of subsequent binary activation. Therefore, it is not necessary to introduce a variance term in the normalization of the binary network. In addition, in the batch normalization of the inference process of the conventional network, a fixed mean of the training set is used, and such a method can be directly used in the binary network without changing [21]. The problem is that the mean value of the feature map of the training set cannot represent the mean value of the corresponding position feature map during the actual inference, so the fixed mean value of the training set is used to normalize the feature map during the inference. The mean of the normalized distribution is not necessarily 0. This phenomenon exists in

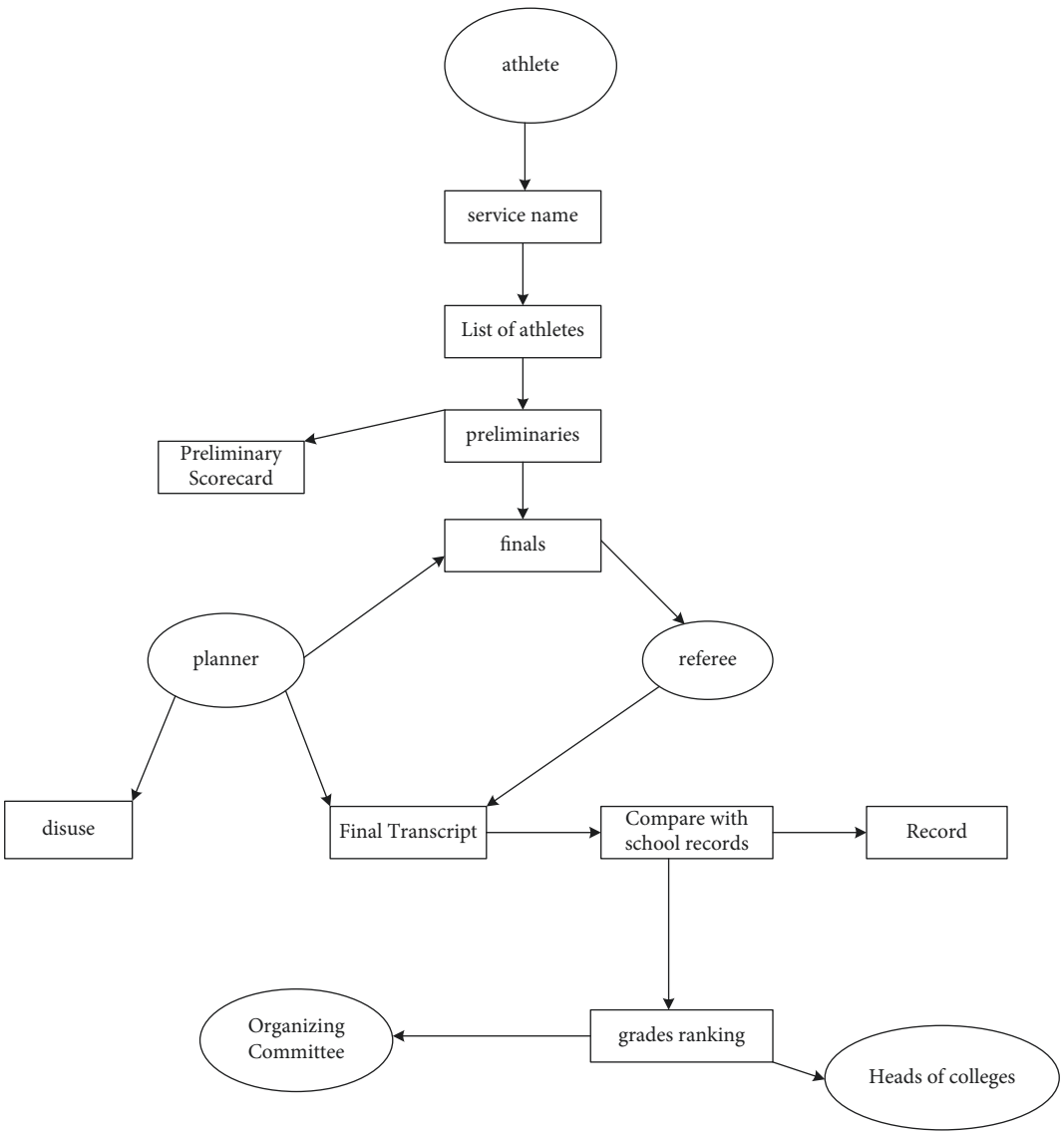


Figure 7: Sports training management information system.

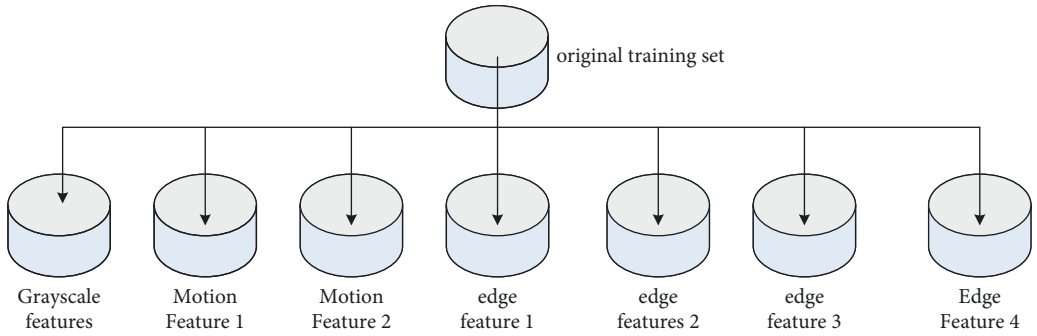


Figure 8: CNN training channel.

regular networks but has little effect because a strictly 0 mean and 1 variance distribution is not necessary for nonlinear activation.

4.3. Experimental Results. In this paper, 60 students from a university are selected as training objects. During the training process, the students' elbows, head, legs, waist, and

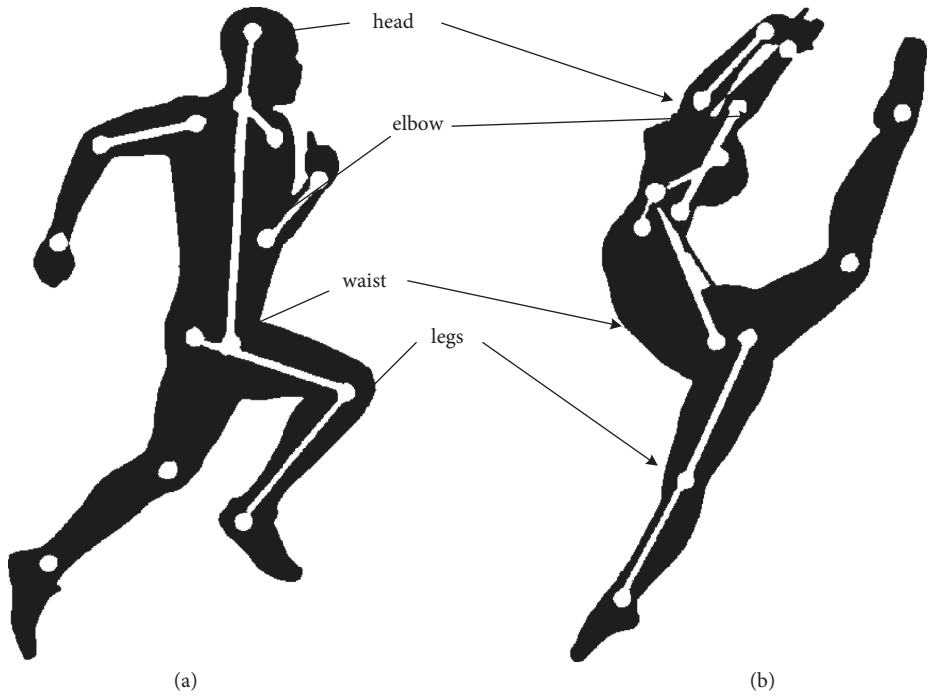


Figure 9: Action recognition feature points.

Table 1: Head training results.

Data	Deviation	Average recognition accuracy (%)
200	0.795 ± 0.027	79.7
400	0.781 ± 0.032	86.6
600	0.736 ± 0.063	92.5

Table 2: Elbow training results.

Data	Deviation	Average recognition accuracy (%)
200	0.865 ± 0.036	76.7
400	0.857 ± 0.042	83.9
600	0.743 ± 0.056	91.6

Table 3: Waist training results.

Data	Deviation	Average recognition accuracy (%)
200	0.665 ± 0.019	81.6
400	0.658 ± 0.022	89.7
600	0.613 ± 0.036	95.1

other parts are selected as identification feature points, as shown in Figure 9.

Firstly, 600 samples are selected from the MSR Action3D dataset for training, and the training results of each part are shown in the tables. Table 1 shows the head training result, Table 2 shows the elbow training result, Table 3 shows the waist training result, and Table 4 shows the leg training result.

Table 4: Leg training results.

Data	Deviation	Average recognition accuracy (%)
200	0.855 ± 0.012	71.7
400	0.848 ± 0.029	79.6
600	0.811 ± 0.038	90.1

It can be seen from Tables 1–4 that after 600 sample training, the accuracy rate of head training is 92.5%, and the accuracy rate of elbow training is 91.6%. The accuracy of waist training is 95.1%, and the accuracy of leg training is 90.1%. Its accuracy rate is more than 90%, so it meets the test requirements.

Finally, this paper conducts actual tests on 60 selected athletes, compares them with traditional calculation methods, and conducts performance tests on the training sports management information system. The overall average recognition accuracy and system recognition rate are obtained, and the results are shown in Figure 10.

It can be seen from Figure 10 that the CNN recognition accuracy test results used in this paper are generally more than 90%, while the traditional recognition accuracy rate is only about 75%, and the highest is not more than 86%. It shows that CNN has a significantly better recognition effect on athletes' movements. And the training management information system in this paper takes about 15.7 s, and the maximum is not more than 10 s. The traditional recognition system takes about 15.7 s, which is about twice the system in this paper. Therefore, it is concluded that the calculation speed of the motion management information system in this paper is faster.

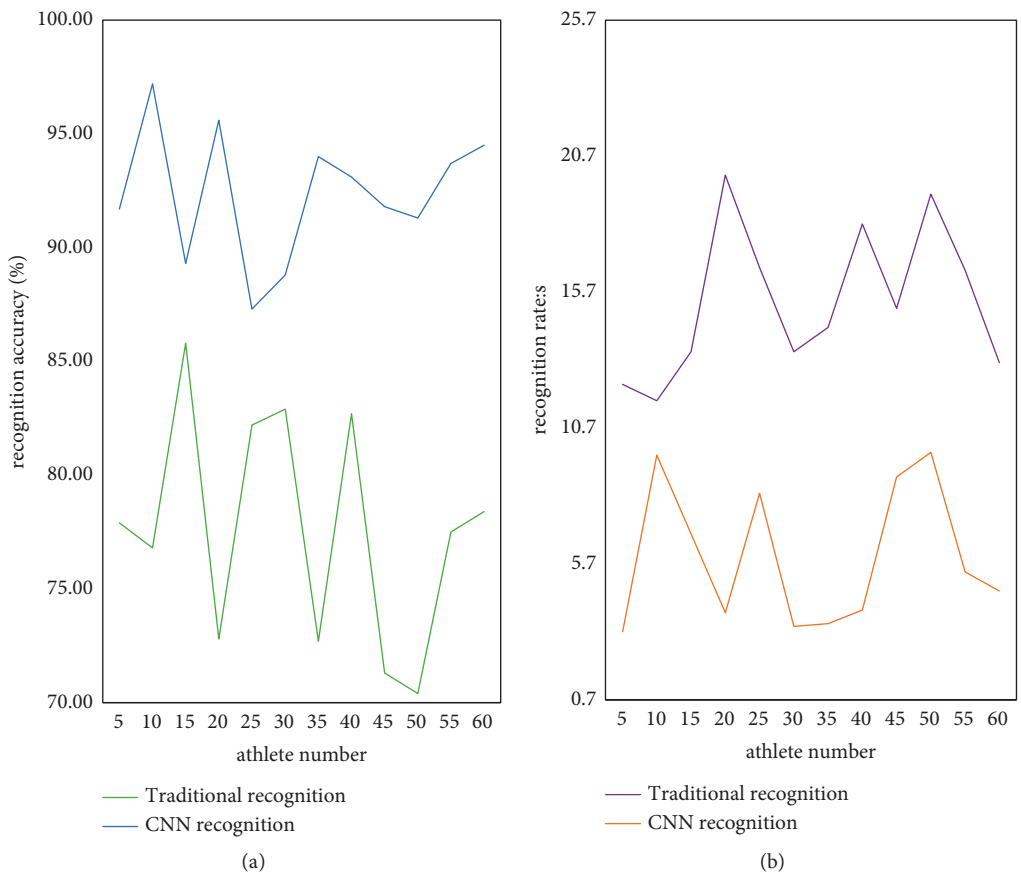


Figure 10: Comparison of recognition results. (a) Recognition accuracy. (b) Recognition rate.

5. Conclusions

In the abstract, this paper firstly gave an overview of the overall content of the full text and then introduced the era background of AI in the introduction, introduced the relevant content of action recognition, and summarized the innovations of this paper. The related work part exemplified some related researches, in order to understand the current situation of the related content researched in this paper. Then, in the theoretical research part, the AI-based action recognition was firstly introduced, including the application of AI, the core technology, and the characteristics of neural networks. Finally, the calculation method of the neural network and the content of the experiment were explained in the experimental part, and the movement characteristics of different parts of the athlete were recognized. The results showed that the artificial neural network method in this paper could recognize significantly better, and the calculation time of the sports management information system was lower.

Data Availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest

The authors declare no conflicts of interest.

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